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RADIO AND SOUND SERVICING

COURSE 75

6-W

IMPORTANT NOTICE

Course 75 contains 8 large schematics. They are located directly below this instruction sheet. These schematics are: Figure 1 (page 6A) and Figure 2 (page 14A) of Lesson 7515; Figure 4 (page 10A), Figure 6 (page 18A), and Figure 7 (page 20A) of Lesson 7520; Figure 9 (page 10A) of Lesson 7545; Figure 4 (page 8A) and Figure 16 (page 20A) of Lesson 7550. You can take these schematics out of this volume and place them alongside the text material as you study those circuits.

After you have finished studying the material in this volume, you may wish to file the schematics with the lessons to which they refer. To make this easy, each schematic has the lesson name near the upper right-hand edge of the sheet and the lesson and page numbers in the lower left-hand corner.

RADIO AND SOUND SERVICING

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Unit Examination . . . . Course 75

SERVICING EQUIPMENT

7505

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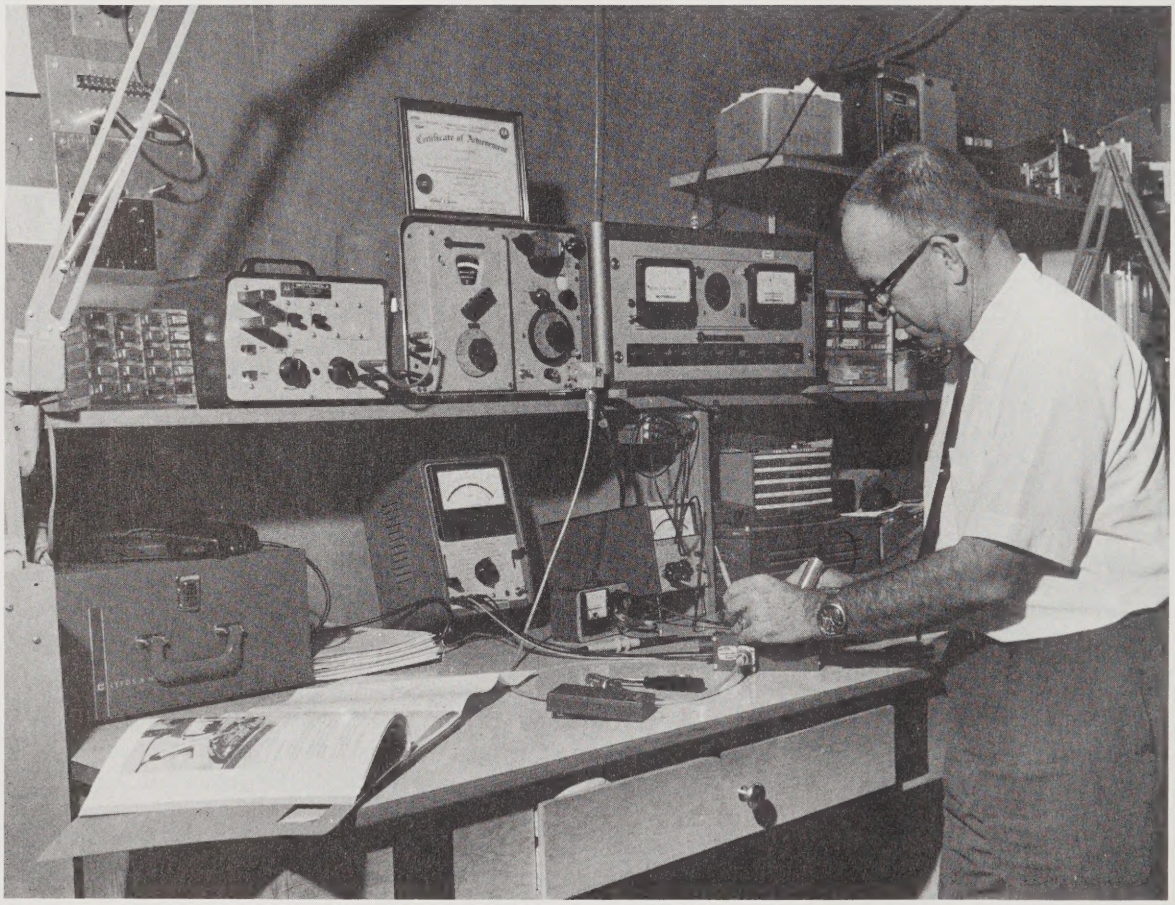

The above photo shows a well-equipped service shop. Note that all the test equipment is within easy reach, small parts are kept in cabinets and the area is well lighted.

Courtesy Motorola, Inc.,
Communications Division

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> *The secret of success in life is for*
> *a man to be ready for his opportunity*
> *when it comes.*
> —*Disraeli*

SERVICING EQUIPMENT

The installation, maintenance and repair of electronic equipment is a large and growing business. Many technicians are employed in a variety of industries to maintain such items as data processing equipment, process control devices, test equipment and communications gear.

A great many electronic technicians are also employed in the repair of home-entertainment electronic devices. Television servicing represents a large fraction of this business, but an important part of it is also provided by radio and audio devices such as tape recorders, phonographs and high-fidelity/stereo systems.

THE BASIC APPROACH TO SERVICING

A systematic procedure in any servicing operation can lead to significant savings in the time required to locate the trouble. It is not a matter of luck when the experienced serviceman locates the defect promptly and restores normal operation.

The competent technician follows a time-tested plan in every service job. He makes certain preliminary checks to reveal the nature of the trouble and to isolate the area not functioning properly. He then makes a series of tests in the affected stage to determine the exact component that is at fault.

Throughout the process, the technician relies on his knowledge of basic circuit theory to lead him to the solution. He does not take a series of wild shots in the dark. Nor does he waste time on tests that have no bearing on the problem.

To become an efficient "troubleshooter" you must follow a logical approach. The speed with which you can find the trouble increases with experience, but from the very beginning you can follow an approach which will greatly improve your efficiency.

REPAIR OR REPLACE? A QUESTION OF ECONOMICS

Before the advent of transistors, home-entertainment equipment was vacuum tube operated and expensive. When a piece of equipment became defective, it was economically practical to service it. Today, however, transistors, integrated circuits and other solid-state devices have found their way into all areas of the consumer market and have greatly changed home-entertainment equipment as well as the service industry. The automobile radios of today are all solid-state devices. Most new home radios are also transistorized. High-fidelity/stereo systems, tape recorders and phonographs are all using transistors. The service shop today must be equipped to service such devices, and anyone who plans to enter service work must be prepared to work on solid-state equipment.

With many solid-state devices it is valid to ask the question, "Is it worth fixing?" When a unit can be replaced for perhaps ten dollars or less, the answer to this question may well be "No," if anything more than battery replacement is required. The serviceman's time must be paid for, and locating the trouble in a five dollar radio may take as long, if not longer, than in a hundred dollar unit. When the cost of repairs approaches the cost of the unit, the owner of the five dollar unit would be money ahead to purchase a new unit. Transistor circuitry is now also used in a great many devices which are expensive enough to justify extensive repair. As a general rule, the replacement cost of the item sets the limit on the extent of repairs that are economically practical.

TEST EQUIPMENT FOR SERVICING

The value of any service technician depends on how quickly he can locate and correct the defects in the customer's equipment. Knowledge and experience play an important part in determining how efficiently he can do this. Servicing efficiency also depends on the variety and quality of test equipment and how well the serviceman is trained in its use.

Many customer problems can be solved with little or no aid from test instruments. However, having the proper tools for the job can lead to more efficient use of the serviceman's time. This lesson will cover the more common types of test equipment used in servicing home-entertainment equipment.

There are many test instruments available which can be helpful. Some of these are considered essential, and many more are occasionally useful but are not actually required to handle most service problems. The instruments considered essential for radio and high-fidelity/stereo servicing are a multimeter, an r-f generator and an audio generator (sine and/or square wave) for audio servicing. If there is a substantial amount of high-fidelity/stereo servicing, the oscilloscope becomes very nearly essential. Tube and transistor testers are also very helpful, and the serviceman should be familiar with their operation and limitations.

Meters

No service shop can function without some means of measuring both ac and dc voltages, resistance and currents. Voltage measurements are often the fastest way to isolate troubles in any electronic equipment. Resistance measurements can be used to detect changes in values of resistors, and can quickly locate shorts or opens. DC current measurements can also be helpful in tracking down troubles. Two distinct kinds of multimeters are widely used in service work—the volt-ohm-milliammeter (VOM) and the high impedance electronic meter employing vacuum tubes or transistors.

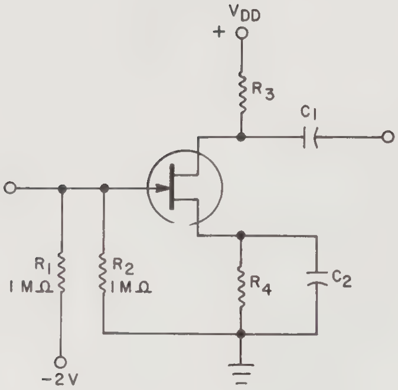


Figure 1

The standard portable VOM consists of a dc current meter movement, a switchable voltage divider network to permit changing ranges on voltage and current measurements, some form of rectifier to convert ac voltages to dc voltages when making ac measurements, and a battery for use in converting the device into an ohmmeter. The primary advantages of such a meter are low cost and compact size. It is handy for carrying on service calls because it requires no external power and can be used anywhere.

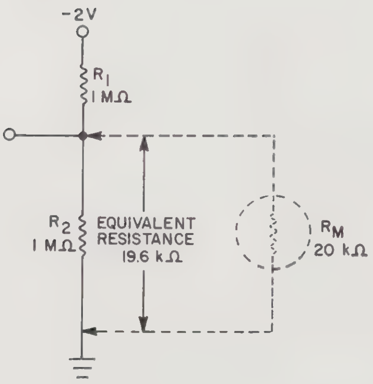


Figure 2

The chief disadvantage of the portable VOM is the relatively low input impedance of its voltmeter section. In many electronic circuits, this places an excessive load on the circuit being measured, and produces an erroneous reading. Let's examine such a situation. Assume that we desire to measure the voltage from gate to ground in the field effect transistor amplifier shown in Figure 1. The gate voltage is normally small and requires a low-voltage range on the meter. The input impedance of the reverse-biased gate circuit is very high, generally on the order of several megohms. With a bias supply of −2 volts and the voltage divider shown, the gate to ground voltage is −1 volt. Assume that you use a 20 kΩ/volt VOM on the 1-volt range to measure this voltage. The internal impedance of the meter on this range is 20 kΩ. This impedance in parallel with R_2 (1 MΩ) produces an equivalent resistance of 19.6 kΩ as shown in Figure 2. The resultant voltage at the gate is therefore −.0384 volt with the meter connected. The true operating voltage cannot be measured with such a meter.

On the other hand, many readings are not seriously affected by such meters. As voltmeters they can be used to accurately check power supply voltages and voltages in low impedance circuits. Most VOM's also permit reasonably accurate measurement of resistance and dc current.

A VOM will usually handle any of the readings that are likely to be taken when making a service call in the customer's home. On the service call you may want to measure supply voltages and to check continuity in some portions of the unit, but you are not apt to be measuring critical operating voltages that require a high impedance meter. If such measurements are required, the unit should come back to your shop.

For use on the service bench, an electronic transistorized or vacuum tube voltmeter (VTVM) is more desirable than a nonelectronic meter. It provides more accurate voltage measurements because its high impedance input causes less loading effect on the circuit being tested. Measurements in high impedance circuits, such as agc lines, can be made accurately with an electronic meter. Unfortunately, most VTVM's cannot measure current.

For all-around service work, a meter should provide accurate readings both at high and low ac and dc voltages. In transistor circuits these voltages may be as low as a fraction of a volt, while in tube circuits the voltages may be several hundred volts or more. A low-voltage range of 1 volt or less is necessary for transistor equipment servicing.

The ac voltage range of the meter should be accurate through the audio-frequency range. Receiver alignment can often be done by connecting an ac meter across the speaker, or a dc meter across the automatic volume control (avc) line. While extreme accuracy is not required in this application, it is helpful if measurements at different audio frequencies are comparable.

The vacuum tube voltmeter provides a high impedance input to reduce circuit loading. This instrument includes a .5 volt dc range which is especially useful when servicing transistor circuits.

Courtesy Radio Corporation of America

This digital multimeter allows the technician to directly read voltage, resistance and current.

Bell and Howell Photo

Many electronic meters can be equipped with an r-f probe for high-frequency ac measurements. However, this is seldom required in radio servicing. It does not qualify as a necessity. The presence and strength of r-f signals can be determined in other ways, such as by avc measurements or audio output measurement if the signal is modulated.

A recent innovation in meters is the digital multimeter. This device has all of the advantages of the electron meters we discussed earlier, plus the added advantage of a digital readout. The meter movement has been replaced by a numerical display device, yielding high accuracy with easy readability.

For both alignment and signal tracing purposes, a good r-f signal generator is a valuable addition to the service shop. Desirable features include relatively accurate calibration, variable voltage output, and choice of modulated or unmodulated output. Frequency coverage of the r-f generator should extend from a low of 250 kHz or less to a high above 110 MHz if FM service is to be performed. The lower limit is necessary because most automobile radios now use 262 kHz as the AM intermediate frequency. The unit should be reasonably stable after a brief warm-up and have a well-calibrated dial which is easy to read and can be easily set to the desired frequency.

An audio modulation signal should be included in the r-f generator and control of the level of modulation is desirable. Many signal generators also provide a separate audio output signal. Because this is usually a fixed frequency such as 400 Hz or 1 kHz, this feature does not serve the same purpose as a separate audio-frequency generator, but it can be used for signal tracing in the audio portion of receivers. A multiplex generator may also be included in the shop if extensive service of stereo FM receivers is contemplated.

Audio Generators

If you are planning to do much service work on high-fidelity/stereo equipment, a good audio generator is desirable. This instrument can be used to determine the frequency response of amplifiers and the effect of tone controls and other frequency compensating devices. Together with a good oscilloscope, a good audio generator is quite useful in the troubleshooting of audio devices.

Some audio generators provide both sinewave and square wave outputs. This is not essential, but the square wave is helpful when used with an oscilloscope to check for distortion in an amplifier.

Tube Testers

Most tube troubles can be found by substituting a new tube in the device being tested. This is often faster and more conclusive than using a tube tester. Also, there are some tubes, particularly those used in high-frequency circuits, which will not operate properly in the circuit even though they test "good" on a tube tester.

However, in any service shop there are occasions when a tube tester is desirable. Some business will come from people who walk in with the tubes from their radio (or TV set) and would like them checked. Self-service testers allow these customers to check their own tubes without involving a technician. This would be lost business if you had no tester. Also, some radios or amplifiers will contain unusual tubes that you may not have in stock. It would be convenient to check these rather than purchasing a special supply to use for a one-time substitution test. Some radios will be almost antique, and contain tubes that you no longer carry in stock. For these reasons, and also because it forms a good impression on the customer, most service shops do include a tube tester.

Tube testers usually fall into one of two categories—emission testers or transconductance testers (mutual conductance). Both types also make other tests, such as shorts, leakage and heater continuity.

An emission tester makes a test to determine whether electron emission from the cathode is normal. Such testers connect all tubes as though they were diodes, with all grids connected to the plate. The meter measures the cathode current. A known ac voltage is applied between these elements, and the amount of current which exists is a good indication of the cathode's ability to emit electrons. Comparison is made to a normal tube of that type by referring to a chart.

The voltages used in such testers are relatively low, usually below the normal operating voltage of the tube, and the conditions of the test are static. Such tests will reveal tubes that are abnormally low in emission but will not show up all tubes that fail to work satisfactorily in radio circuits. Conversely, some tube which cannot pass the emission test may continue to give satisfactory service in an actual circuit. As a general rule, the technician is still well advised to replace any questionable tube.

A transconductance tester checks the amplifying ability of vacuum tubes. This is a more reliable test than the emission test, although it does not reveal all tubes which perform unsatisfactorily.

Transconductance is defined as the ratio of a change in plate current to the change in grid voltage which caused it. It is measured in micromhos or microsiemens. If a .5 volt change of grid voltage causes a 1 mA change in plate current, the transconductance is .001/.5 or .002 mhos (or 2000 micromhos). Such a value is typical of many triode voltage amplifiers. Pentodes usually have a higher transconductance.

Tube testers which check transconductance may use either dc or ac voltages on the tube elements. The less expensive models usually use ac to save the cost of a rectifier and filtering network.

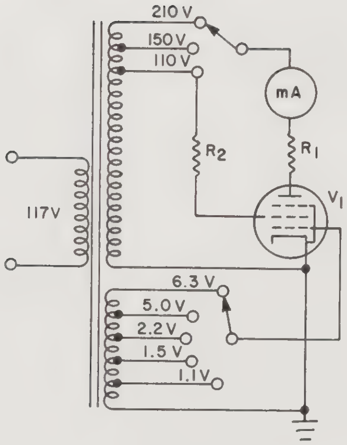


Figure 3

Figure 3 shows a schematic diagram of an ac version of a transconductance-type tube tester. V_1 is the tube being tested. Taps on the transformer allow the proper plate voltage to be selected for the type of tube being tested. The meter is in series with the plate circuit and indicates the plate current. The low-voltage tap supplies a signal to the control grid which controls the plate current. If the transconductance is low, the plate current will not be high enough and the meter will indicate a low transconductance. Some transconductance testers include a GOOD-BAD scale to help determine the condition of the tube. In order to obtain a similar meter reading on a variety of tubes, the grid and plate voltages are set such that current through the meter above a certain level indicates a good tube.

In addition to testing either emission or transconductance, tube testers usually contain a circuit which tests for shorts and leakage. The short test should be made before testing the plate current. In this test a low ac voltage is obtained from a transformer. One side of the transformer connects to all elements of the tube through a switching arrangement like that shown in Figure 4. The other side of the transformer connects through a resistor and the neon lamp to the normally open side of the set of switches. Each switch, in turn, is used to connect the neon lamp to a tube element. If a short is present to any other tube element, current will be through the short and the lamp will glow.

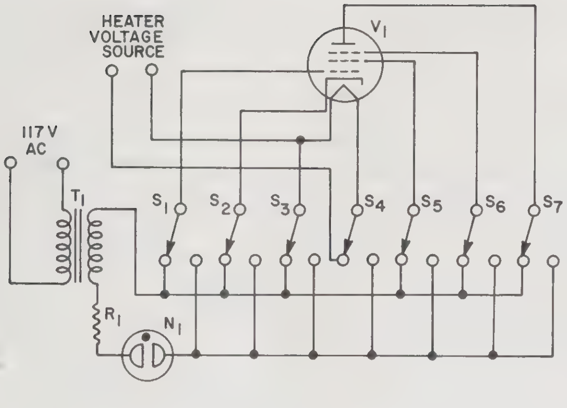


Figure 4

The same setup is used to test for leakage resistance. Leakage resistance is equivalent to having a high resistance short between elements, and if the resistance is below a normal value, the neon lamp will glow.

The short test is usually made with heater voltage applied to the tube because some shorts show up only after heat has caused the tube elements to expand. When switch S_4 in Figure 4 is set to the right, the heater circuit is opened but a short should be indicated by the neon lamp because the heater itself provides a low resistance path for its current through S_3. If the lamp did not light, it would indicate that the tube heater was open.

Transistor Testers

In well-designed circuits, transistor failure is uncommon. As with tube testers, transistor testers are not absolutely necessary. They are, however, handy because it is almost impossible to carry a complete stock of replacement transistors for substitution purposes. Because many transistors are soldered directly into the circuit, the tester should be of the "in circuit" type so the transistor does not have to be removed. Most testers measure beta and leakage current, though the latter test must be ~~made out-of-circuit~~. Circuit power must always be off before performing a test.

Figure 5 shows the simplified schematic of an ac powered in-circuit transistor tester. The most important quality test for transistors is to determine beta or h_{fe}, the base-to-collector current gain. A tester may be designed to measure either ac or dc beta. Typically, an ac powered tester will measure ac, and a battery powered unit, dc.

In Figure 5, the small ac voltage obtained from the T_1 secondary is applied between the emitter and collector of the transistor under test. R_3 supplies an

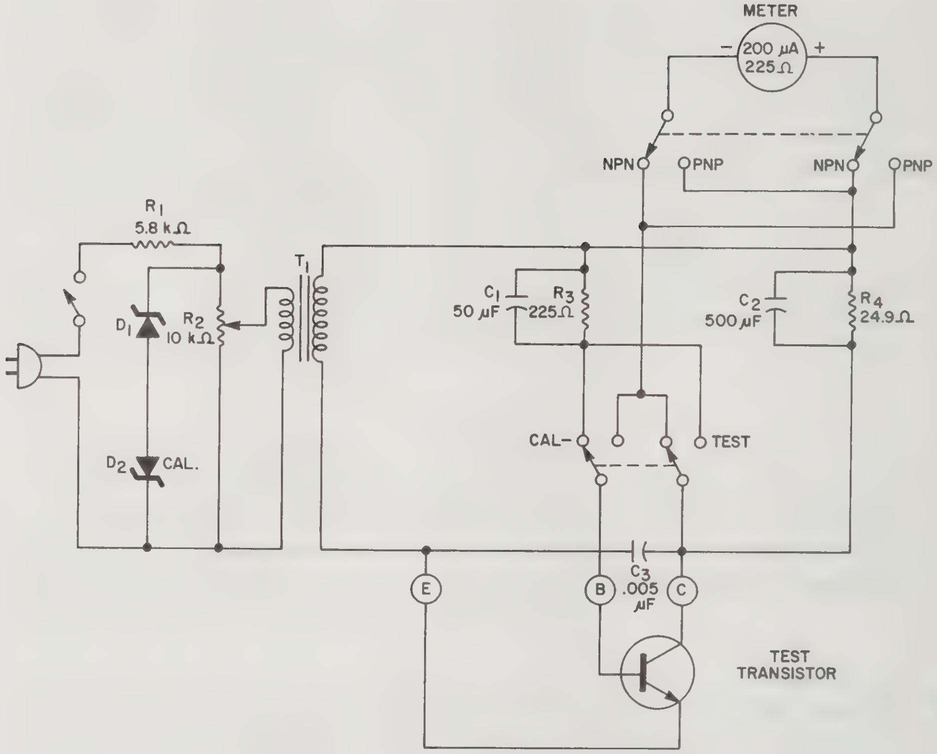


Figure 5

ac signal to the base of the transistor under test. Test leads connect to the transistor under test, which does not need to be removed from the circuit in which it normally operates.

To use the instrument, the function switch is set to the CAL position. This places the meter in parallel with the collector load R_4. The calibration control, R_2, is adjusted to obtain full-scale deflection of the meter. This condition sets the collector current at 2 mA.

The function switch is then set to the TEST position, connecting the meter in the base circuit in place of R_3. Because R_3 is equal to the internal resistance of the meter, the base current remains the same when the function switch is in the TEST position. The meter now indicates base current, and because the collector current is known, the meter can be directly calibrated in terms of beta.

Figure 5 includes a switch which reverses the meter so both NPN and PNP-type transistors can be tested. Because ac voltages are used on all elements, the transistor conducts on one half cycle whether it is PNP or

The following Practice Exercise questions cover the subjects which you have just studied. They are:

THE BASIC APPROACH TO SERVICING

REPAIR OR REPLACE?—A QUESTION OF ECONOMICS

TEST EQUIPMENT FOR SERVICING

METERS

AUDIO GENERATORS

TUBE TESTERS

1. What tends to establish the upper limit at which repairs are economically practical on inexpensive radios?
2. What is the chief disadvantage of a low impedance volt-ohm-milliammeter?
3. List at least three measurements which can be made satisfactorily with a typical VOM.
4. The transistorized voltmeter is well suited to measurement of low voltages in high impedance circuits. True or False?
5. For what two operations can an r-f signal generator be used in radio troubleshooting work?
6. An audio generator is helpful in determining the frequency response of a high-fidelity amplifier. True or False?
7. Substitution of tubes in the equipment being serviced is not a good method of checking tubes. True or False?
8. Name the two basic types of tube testers.
9. If a tube tester connects the tube to be tested as a diode, with the grids and plates connected together, is it an emission tester or a transconductance tester?
10. What ratio establishes the transconductance of a tube and in what units is it usually measured?
11. How can the meter in the circuit of Figure 3 be calibrated directly as GOOD or BAD when not all types of tubes have the same value of transconductance?

12. In the test circuit of Figure 4, which switch must be toward the right to reveal a short between the cathode and the control grid?

13. Why is heater voltage usually applied to the tube during short tests?

14. For testing tubes in a tube tester, which of these tests should be performed first—the transconductance test or the short test?

This transistor tester will test transistors without removing them from the circuit. In addition to testing conventional junction transistors, this unit will also test field effect transistors.

Courtesy Sencore, Inc.

NPN. However, the direction of current through the transistor is reversed in the two instances, and it is necessary to reverse the meter for proper operation.

Zener diodes D_1 and D_2 limit the input voltage to the transistor. They also serve as voltage regulators to ensure that the applied voltage remains constant after the calibration control has been set.

Notice that the resistance values in the tester are all low enough that components in the circuit under test have virtually no effect. If the collector-to-emitter resistance exceeds about 50 ohms in the unit being tested, the readings obtained with the transistor in the circuit are as accurate as they would be if the transistors were entirely out of the circuit.

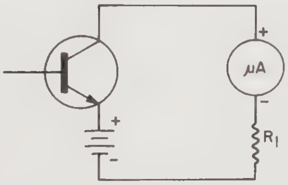


Figure 6

In addition to beta tests, most transistor testers include circuits to check for shorts and abnormally high leakage current. These tests require the application of dc voltages rather than ac because the elements are reverse biased during the tests. Figure 6 shows a test setup for checking leakage between collector and emitter with the base open. In a normal transistor a very small current will exist in this circuit. If any junction is shorted or has excessive leakage, a much higher current will exist. Similar tests can be made between any two elements.

THE SERVICE BENCH

The service bench should be carefully set up to conserve the serviceman's time as much as possible. The necessary test equipment should be assembled in a manner that permits easy connection to the units being tested. Adequate lighting without shadows is a necessity. Storage for replacement parts should be convenient and well marked.

Power to the bench is an important consideration. Some units being serviced are of the transformerless ac-dc variety in which one side of the ac line goes directly to the chassis. When working on such a unit with test instruments which also connect to the ac line, isolation from the line is important. An isolation transformer should be used between such units being serviced and the line.

An isolation transformer is a transformer with a 1:1 turns ratio, which serves to prevent direct connection between the line and the device connected to it. An even better choice is a voltage variable transformer. This type of transformer allows you to make tests with lowered or raised power line voltages, which can be useful in testing for "borderline" operation.

If automobile radios are to be serviced, the bench should also be equipped with a battery eliminator. These devices provide a convenient source of dc power at battery voltages. To be useful on portable transistorized equipment, this supply should have a variable output, permitting its use at several voltage levels. The auto radios will nearly all require 12 volts, while 9 volts, 6 volts and 4.5 volts will be encountered in some transistor portables. Many supplies intended for substitution in place of a battery can also be used as battery chargers. Any supply to be used as a battery substitute must have good regulation under varying loads, and must be very well filtered.

SOURCES OF SERVICING INFORMATION

The well-equipped service shop should contain a library of servicing information on all the types of units normally serviced. This can represent a sizable investment, but is well worth the cost. Much time can be wasted in circuit tracing if the necessary schematics are not available. Attempting to trace the circuitry on a printed circuit board without a schematic or circuit layout diagram is a frustrating task.

Several organizations make a business of supplying servicing data to the repairman. These service sheets provide schematic diagrams, pc board layouts and alignment instructions for nearly every model of equipment sold. This type of material is available through parts distributors, and is also advertised in many of the electronics publications.

In addition to such sources, a wealth of service information can be obtained from manufacturers of radio equipment. Service manuals are prepared for most equipment and can be obtained directly from the manufacturers. Most of the leading manufacturers will send technical data on their equipment on a regular basis, if you ask to be placed on their mailing list.

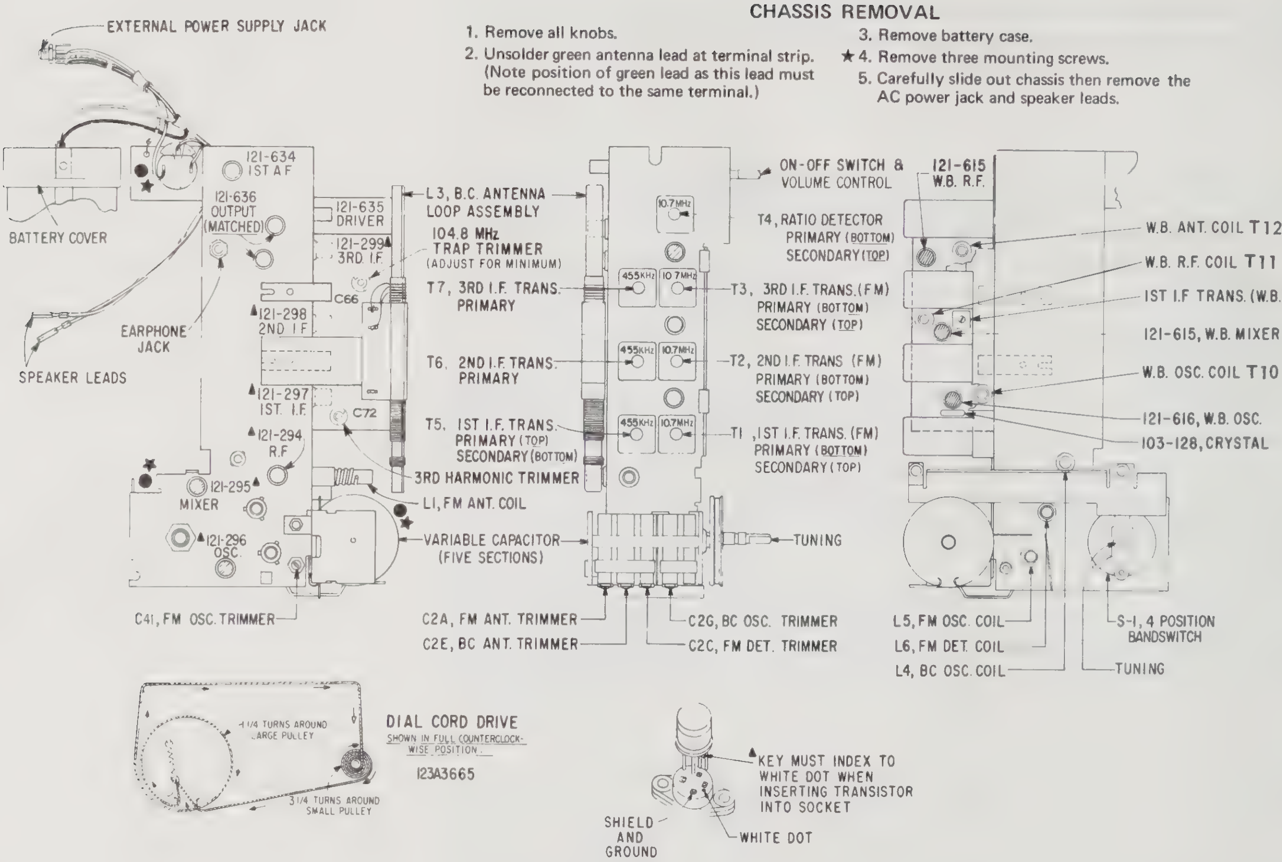
There are also a number of good publications devoted to the electronic servicing industry. These will help to keep you informed of the latest innovations in circuits for all forms of home-entertainment devices. Several contain regular columns of contributions from working service technicians, covering faults that develop in particular pieces of equipment.

It takes both time and money to accumulate a good library of service information. It is, however, one of the most valuable investments you can make in your shop. You cannot do an efficient job on the variety of equipment you will be called upon to service without proper circuit data.

HAND TOOLS

In addition to the test equipment required, the serviceman needs a well-chosen set of hand tools. The proper tools can materially reduce the time required to replace defective parts. Failure to use the proper tools can result in damage to the unit being repaired.

Probably the most important hand tool on the list is the soldering iron. For work on printed circuit boards, a low-wattage iron (20 to 40 watts) with a small tip is required. Heavy duty irons are not recommended for such work, as excess heat can damage semiconductors or the printed circuit board. For work in wired circuits, a somewhat higher wattage iron or soldering gun is usually used. For most electronic work, 100 watts is adequate.



CHASSIS REMOVAL

1. Remove all knobs.
2. Unsolder green antenna lead at terminal strip. (Note position of green lead as this lead must be reconnected to the same terminal.)
3. Remove battery case.
★4. Remove three mounting screws.
5. Carefully slide out chassis then remove the AC power jack and speaker leads.

EXTERNAL POWER SUPPLY JACK
BATTERY COVER
SPEAKER LEADS
EARPHONE JACK
121-634 1ST A F
121-636 OUTPUT (MATCHED)
121-635 DRIVER
121-299 3RD I.F.
C66
121-298 2ND I.F.
121-297 1ST. I.F.
C72
121-294 R.F.
121-295 MIXER
121-296 OSC.
C41, FM OSC. TRIMMER
L3, B.C. ANTENNA LOOP ASSEMBLY
104.8 MHz TRAP TRIMMER (ADJUST FOR MINIMUM)
T7, 3RD I.F. TRANS. PRIMARY
T6, 2ND I.F. TRANS. PRIMARY
T5, 1ST I.F. TRANS. PRIMARY (TOP) SECONDARY (BOTTOM)
3RD HARMONIC TRIMMER
L1, FM ANT. COIL
VARIABLE CAPACITOR (FIVE SECTIONS)
C2A, FM ANT. TRIMMER
C2E, BC ANT. TRIMMER
10.7MHz
455KHz
ON-OFF SWITCH & VOLUME CONTROL
T4, RATIO DETECTOR PRIMARY (BOTTOM) SECONDARY (TOP)
T3, 3RD I.F. TRANS. (FM) PRIMARY (BOTTOM) SECONDARY (TOP)
T2, 2ND I.F. TRANS (FM) PRIMARY (BOTTOM) SECONDARY (TOP)
T1, 1ST I.F. TRANS. (FM) PRIMARY (BOTTOM) SECONDARY (TOP)
TUNING
C2G, BC OSC. TRIMMER
C2C, FM DET. TRIMMER
121-615 W.B. R.F.
W.B. ANT. COIL T12
W.B. R.F. COIL T11
1ST I.F TRANS. (W.B.) T9
121-615, W.B. MIXER
W.B. OSC. COIL T10
121-616, W.B. OSC.
103-128, CRYSTAL
L5, FM OSC. COIL
L6, FM DET. COIL
L4, BC OSC. COIL
S-1, 4 POSITION BANDSWITCH
TUNING
4 1/4 TURNS AROUND LARGE PULLEY
3 1/4 TURNS AROUND SMALL PULLEY
DIAL CORD DRIVE
SHOWN IN FULL COUNTERCLOCKWISE POSITION
123A3665
KEY MUST INDEX TO WHITE DOT WHEN INSERTING TRANSISTOR INTO SOCKET
SHIELD AND GROUND
WHITE DOT

TRANSISTOR AND TRIMMER LAYOUT

This sample page is typical of the information supplied in a manufacturer's service manual. It shows all of the alignment points as well as the location of the major components.
Courtesy Zenith Radio Corporation

Your set of hand tools should include a good pair of diagonal cutters, long nose pliers, a selection of screwdrivers and nut drivers, and suitable alignment tools. A wire stripper is a handy addition. Spring-type heat sinks are also helpful for work on solid-state circuits. They grip the unit to be soldered, while allowing both hands free for the soldering operation. Experience will show what tools should be added to the basic lineup.

CUSTOMER RELATIONS

The serviceman should always remember that part of his job is maintaining good relations with the customers he serves. Whether he is a self-employed businessman or the employee of a large service shop, this is an important consideration.

Such things as a neat personal appearance, good manners when speaking with customers in the shop, on the telephone or in the customer's home, and prompt attention to the customer's problems all have a bearing on your value as a serviceman. Never provoke or feed an argument. Diplomacy will solve more problems than shouting.

In addition to these fundamental considerations, there are a number of small practices which can improve the customer's opinion of your service. If these are regularly included in your service routine, they will require little extra time and are apt to improve the repeat business you obtain.

You should always clean a unit thoroughly before returning it to the customer. There is usually a considerable accumulation of dust on the chassis and inside the cabinet. This should be removed either with air pressure, vacuum, or by wiping. A small dry paint brush can help you reach the tight spots. Plastic cabinets are easily cleaned with a damp cloth, while wood cabinets should be cleaned with furniture polish. Never spray contact cleaner on a plastic surface. Many such cleaners contain solvents and may dissolve a plastic surface. Also, avoid rubbing off calibration marks or labels.

Check such items as dial cord tension and proper functioning of dial lights. Replace knobs carefully. Wind the line cord up neatly. Don't tie it in knots or let it hang loose. Replace all missing hardware with a close match. Some shops enclose the finished repair in a plastic bag. This is especially desirable in wet weather.

These may seem like insignificant matters, but they do affect the image you leave with your customers. A little extra effort will be repaid by the customer's return when he again needs service, and by his recommendation of your work if someone else needs a repair job. Conversely, if he sees that you have little concern for the outward appearance of his receiver, he may assume that the repair itself was poorly done.

SUMMARY

All efficient troubleshooting follows a systematic plan, designed to first determine the nature of the trouble, isolate the defective stage, and then locate the fault. This is true in both transistorized equipment and in tube circuits.

The speed with which a serviceman can locate the defect is determined by the effectiveness of his plan of attack, his knowledge of basic circuits, and his skill at making effective use of the test equipment available.

Circuit diagrams, layout drawings and alignment information are great helps to the serviceman, and expenditures for a library of such information are repaid by the time savings which they effect.

A good assortment of hand tools can add to the efficiency of servicing work. The selection of tools is usually a matter of personal preference, but should include suitable soldering irons, wire cutters, and other tools that are essential to servicing work.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

TEST EQUIPMENT FOR SERVICING

TRANSISTOR TESTERS

THE SERVICE BENCH

SOURCES OF SERVICING INFORMATION

HAND TOOLS

CUSTOMER RELATIONS

15. Some transistor testers permit checking the transistor without removing it from the circuit in which it is used. True or False?

16. In the transistor tester shown in Figure 5, what is the reason for adjusting calibration control R_2 with the meter in the collector circuit when testing for beta?

17. Assume that the transistor being tested is in a circuit with 1000 ohms of resistance from collector to emitter. What effect would this have on the reading obtained when the meter is in the collector circuit?

18. If a PNP transistor were being tested for leakage in the circuit of Figure 6, what changes would be necessary in the circuit?

19. Why is it desirable to use an isolation transformer when servicing an ac/dc receiver?

20. Name three sources of circuit diagrams and service data which the serviceman may use to build up a library of useful information.

21. A suitable soldering iron for work on printed boards should have a wattage rating greater than 100 watts. True or False?

PRACTICE EXERCISE SOLUTIONS

1. The replacement cost of the unit. No customer should pay more for repairs than the cost of a new unit.

2. The loading effect it has on high impedance circuits.

3. AC line voltage, supply and battery voltages, and resistance measurements. If the meter has a dc current section, it will usually give accurate current readings as well.

4. True

5. Alignment and signal tracing.

6. True

7. False—This is often the fastest and most reliable of checking tubes if the replacement tubes are available.

8. Emission testers and transconductance testers.

9. An emission tester.—This type of tester indicates the emission from the cathode.

10. Transconductance is the ratio of the change in plate current to the change in grid voltage which produces it. This is usually measured in micromhos.

11. Different voltages are applied to different tubes to make their plate currents comparable.

12. Either S_1 or S_2.

13. Because some tubes contain shorts after heating which are not present when the tube is cold.

14. The short test.—If a short is present, the tube should be discarded without a quality test because a short might damage the tester during transconductance or emission tests.

15. True

16. To establish the value of collector current at 2 mA. The voltages required to produce this current will differ from one type of transistor to another.

17. Virtually none.—A 1000-ohm resistance connected in parallel with the collector load of 24.9Ω will not alter either the resistance in the collector circuit or the collector current significantly.

DE VRY INSTITUTE OF TECHNOLOGY
4141 BELMONT AVENUE, CHICAGO, ILLINOIS 60641

ONE OF THE
BELL & HOWELL SCHOOLS

7505A
EXAMINATION CHECK SHEET

7505A

1. A - A LOGICAL APPROACH TO TROUBLESHOOTING IS TO -- DETERMINE THE NATURE OF THE TROUBLE AND THEN LOCATE THE DEFECTIVE STAGE.
Once the defective stage is located, tests can be made in that stage to determine the exact defect.

2. D - MINIMUM REQUIREMENTS OF TEST EQUIPMENT IN A RADIO SERVICE SHOP INCLUDE -- PROPER METERS AND A SIGNAL GENERATOR.
Other instruments such as tube testers, sweep generators or oscilloscopes can make the job easier, but are generally not essential.

3. D - THE CHIEF ADVANTAGE OF AN ELECTRONIC METER OVER A SIMPLE VOLT-OHM-MILLIAMMETER IS THAT -- IT HAS A HIGHER INPUT IMPEDANCE.
The higher input impedance permits measurements in high impedance circuits without a loading error.

4. B - AN IMPORTANT APPLICATION OF AN R-F SIGNAL GENERATOR IS IN -- ALIGNING THE TUNED CIRCUITS OF A RADIO RECEIVER.
The r-f signal generator is used in aligning and signal tracing the i-f and r-f stages of a radio receiver.

5. D - AN R-F GENERATOR FOR BOTH AM AND FM RADIO SERVICE WORK SHOULD HAVE A FREQUENCY RANGE FROM -- 250 kHz TO 110 MHz.
The AM i-f frequencies can go as low as 250 kHz while the highest AM broadcast station frequency is 108 MHz.

6. D - TUBE TESTERS ARE USUALLY CLASSED AS -- TRANSCONDUCTANCE OR EMISSION TESTERS.
The emission tester checks the cathode current under dc conditions while the transconductance tester checks plate current under ac signal conditions.

7. D - THE MOST CONCLUSIVE TUBE TEST IS -- REPLACEMENT WITH A TUBE KNOWN TO BE GOOD.
Although transconductance testers test the tubes under ac conditions, they cannot duplicate all the operation conditions found in every circuit. For this reason, substitution is often the only conclusive test.

8. D - TRANSISTOR TESTERS ARE PRIMARILY USED TO FIND -- OPEN OR SHORTED TRANSISTORS AND BETA RATINGS.
Most transistor testers test for leakage as well as current gain.

9. A - THE FUNCTION OF AN ISOLATION TRANSFORMER IS TO -- PREVENT DIRECT CONNECTION BETWEEN CHASSIS GROUND AND THE AC LINE.
The isolation transformer reduces the shock hazard by isolating the ac line from the unit under test.

10. D - SOLDERING IRONS FOR USE ON PRINTED CIRCUIT BOARDS SHOULD BE RATED AT -- 20 TO 40 WATTS.
A 20 to 40 watt iron is the most suitable size for pc board work. A higher heat can damage the board.

QUESTIONS

IMPORTANT—These instructions **MUST** be accurately followed to avoid loss, or errors in grading.

Indicate your answer on this sheet by filling in the box for the most correct answer to each question, as illustrated in the example below.

When all questions have been answered, place the answer card in the proper position to line up the boxes on the card with the boxes on the sheet.

Next, copy the complete lesson code into the space provided on the card, and fill in the answer boxes to correspond with those previously filled in on this sheet.

Before mailing, be certain your correct student number, name and address appear on the card.

LESSON CODE
7505A

Example: The National Football League team representing the city of San Francisco is known as the
(A) 49ers. (B) Lions. (C) Giants. (D) Packers.

A ■
B ☐
C ☐
D ☐

1. A ☒ B ☐ C ☐ D ☐
A logical approach to troubleshooting is to
(A) determine the nature of the trouble and then locate the defective stage. (B) follow the same steps in all cases. (C) memorize all the possible defects that may occur. (D) measure every voltage in the circuit.

2. A ☐ B ☐ C ☐ D ☒
Minimum requirements of test equipment in a radio service shop include
(A) an oscilloscope and sweep generator. (B) a good tube tester. (C) an oscilloscope only. (D) proper meters and a signal generator.

3. A ☐ B ☐ C ☐ D ☒
The chief advantage of an electronic meter over a simple volt-ohm-milliammeter is that
(A) it has a lower input impedance. (B) it has more accurate calibration. (C) it is less expensive. (D) it has a higher input impedance.

4. A ☐ B ☒ C ☐ D ☐
An important application of an r-f signal generator is in
(A) checking distortion in a high-fidelity amplifier. (B) aligning the tuned circuits of a radio receiver. (C) checking continuity of a circuit. (D) checking leakage resistance of a vacuum tube.

5. A ☐ B ☐ C ☐ D ☒
An r-f generator for both AM and FM radio service work should have a frequency range from
(A) 540 kHz to 10 MHz. (B) 250 kHz to 1650 kHz. (C) 88 MHz to 110 MHz. (D) 250 kHz to 110 MHz.

6. A ☐ B ☐ C ☐ D ☒
Tube testers are usually classed as
(A) triode or pentode testers. (B) open or short testers. (C) ac or dc testers. (D) transconductance or emission testers.

7. A ☐ B ☐ C ☐ D ☒
The most conclusive tube test is
(A) an emission test. (B) an ohmmeter measurement. (C) a visual inspection. (D) replacement with a tube known to be good.

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Transistor testers are primarily used to find
(A) whether a transistor is PNP or NPN. (B) transconductance and emission. (C) the breakdown voltage of transistors. (D) open or shorted transistors and beta ratings.

9. A ☒ B ☐ C ☐ D ☐
The function of an isolation transformer is to
(A) prevent direct connection between chassis ground and the ac line. (B) step up voltages to higher levels. (C) convert dc to ac. (D) convert ac to dc.

10. A ☐ B ☐ C ☐ D ☒
Soldering irons for use on printed circuit boards should be rated at
(A) 1 kilowatt. (B) at least 100 watts and preferably more. (C) 1 watt or less. (D) 20 to 40 watts.

PRACTICE EXERCISE SOLUTIONS (Continued)

18. Both the battery voltage and the meter polarity would need to be reversed.

19. The transformer provides isolation between the chassis of the receiver and the ac line so that the test instruments may be connected to chassis ground without danger of shorting the line.

20. Service data is published by several companies which specialize in this type of material; it appears in many electronics publications and is usually available directly from the manufacturers.

21. False—Low wattage irons—40 watts or lower—are preferable when soldering printed circuit boards.

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TROUBLESHOOTING TECHNIQUES

7510

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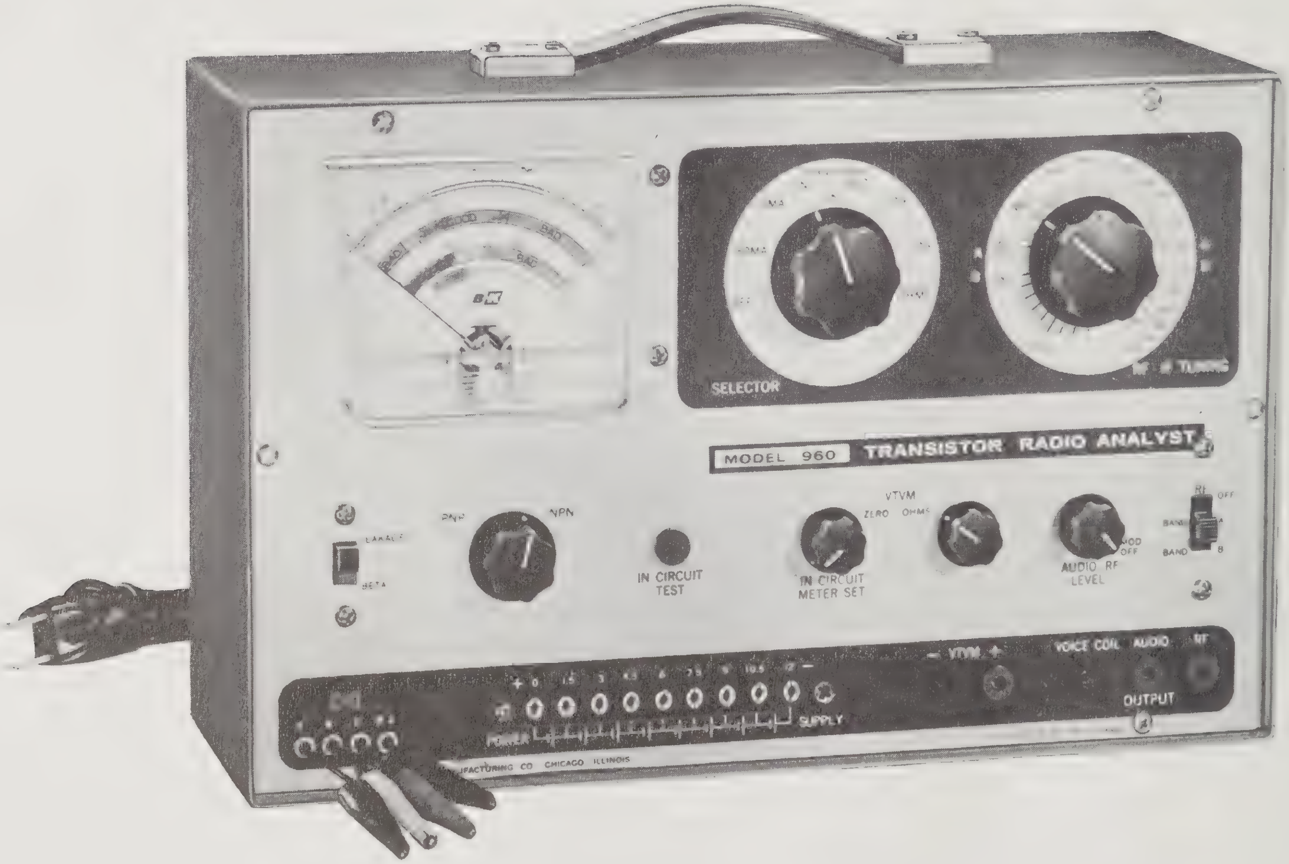

This test unit provides all the necessary functions for servicing transistorized AM broadcast receivers. Included are a transistor tester, power supply, audio generator, r-f/i-f generator and a VTVM.

Courtesy B and K Division
Dynascan Corp.

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> *Not unless we fill our existence with*
> *an aim do we make it life.*
> *—Reichel*

TROUBLESHOOTING TECHNIQUES

There are a number of different methods of troubleshooting. The different methods are made possible by the various kinds of test equipment and measuring instruments available. Although most experienced service technicians proceed in much the same way, their individual routines differ in some respects.

Generally speaking, the basic troubleshooting procedure consists of preliminary checks followed by one or more testing methods. Most often, the main differences between individual procedures lie in the selection of the testing methods and the order in which they are used. This lesson describes the commonly used methods. As you gain experience, you will make most use of those methods that are best suited to your needs.

BASIC TROUBLESHOOTING PROCEDURE

If we omit details regarding specific types of tests, we can outline the basic troubleshooting procedure as follows:

1. DETERMINE THE SYMPTOM. Listen to the owner's description or complaint, and observe the operation, or lack of operation, of the faulty unit.

2. MAKE INITIAL CHECKS. If the unit operates at all, manipulate tuning controls, volume controls and other controls to observe their effect, if any, on the operation. For a battery operated unit, check the condition of the battery if the symptom could result from a bad battery.

3. LOCATE THE FAULTY STAGE. Remove the defective unit from its cabinet. Make a thorough visual examination of the unit, looking for burnt or broken components. With the aid of test instruments, check to find out which section or stage in the unit is defective. In some instances, you may have obtained this information from your initial checks.

4. LOCATE THE FAULTY CIRCUIT. Make the necessary tests to find which circuit in the faulty stage contains the defect. For example, in a transistor stage the defect may be in the base circuit, the emitter circuit or the collector circuit.

5. FIND THE DEFECT. After you've found the circuit that contains the defect, make further tests to locate the actual defect. This may involve a faulty circuit component, or some other circuit trouble.

The exact procedure for locating a defect depends on the nature of the defect. Therefore, variations of the basic troubleshooting procedure are generally used for different types of troubles.

After you have found the trouble, install the new part, make the adjustments or do whatever else is necessary to restore normal operation.

TESTING METHODS

Several basic testing methods are used in troubleshooting. Each has advantages and limitations with which you should be familiar so you can select the methods best suited for finding each type of trouble.

One basic test method is the **DYNAMIC TEST**. It consists of observing how the circuits of the faulty unit affect the signal. The two common types of dynamic tests are signal injection and signal tracing.

The other basic test method is the **STATIC TEST**. It is a check of circuit conditions with no signal applied to the unit. Examples of static tests are voltage, current and resistance measurements.

In addition to the dynamic and static tests, there are a few other testing methods. In general, they take the form of observing the results of opening circuits and replacing or shorting out various components.

Signal Injection

SIGNAL INJECTION requires the use of a test signal supplied by an external source such as a signal generator. The idea is to introduce the test signal at various points in the defective unit, and observe the output, such as the sound produced in the speaker. This method of testing is also known as **SIGNAL SUBSTITUTION** because the test signal from the generator is substituted for the regular signal.

To illustrate this method, a block diagram of a broadcast band radio receiver is shown in Figure 1. R_1 in Figure 1 represents the volume control. Labeled TP for test point, the ungrounded terminal of R_1 is usually the first point at which a signal is injected. This procedure divides the receiver into two sections, a-f and r-f. An audio-frequency signal is injected at the TP because all stages following this point are a-f amplifiers.

Connect a .1 μF capacitor in series with the probe leads of the generator, unless you know that the generator has a blocking capacitor in series with its output terminal. This capacitor prevents changing the dc voltages in the circuit under test. Connect the generator ground lead to a ground point in the receiver, such as the chassis.

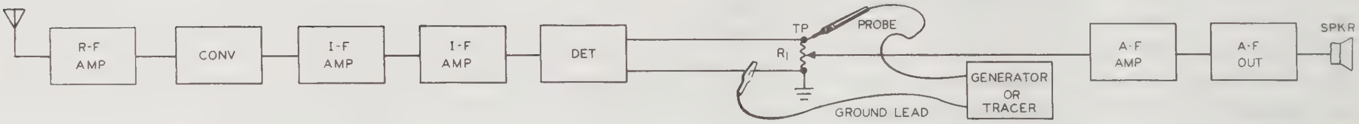


Figure 1

Set R_1 to maximum, and set the signal generator for a low-level output. When the signal generator does not provide for control of the a-f output level, you may have to construct an external attenuator.

With the generator probe touched to the TP, a normal audio tone produced by the speaker indicates that the a-f section is in good condition, and the trouble lies ahead of the volume control. Abnormal or no sound in the speaker indicates trouble in the a-f section.

The faulty stage can be isolated by injecting test signals at points between stages in the suspected section. For example, if the a-f section is indicated to be faulty by the check at the TP, touch the generator probe to a point between the a-f amplifier and a-f output stage. The collector of the a-f amplifier transistor or the base of the output transistors are good points to use in the transistor receivers. In tube receivers, touch the probe to the grid of the output tube. If a normal sound is now produced, the trouble is in the first audio stage. If not, the defect is between this point and the speaker.

If normal output is obtained when a signal is injected at the TP, yet the receiver does not produce an output when tuned to a radio station, look for trouble in the r-f and i-f sections. Set an r-f signal generator to the i-f frequency of the receiver and use a modulated signal. With the receiver volume on full, inject a low-level signal at the output or input of each stage in the i-f section, including the converter. Work from the detector toward the front end of the receiver. If a normal sound is produced, all stages following the test point are in good condition.

Adjust the generator whenever necessary to keep the speaker sound output at a low level. This is to prevent overloading and false indications. When you reach a point at which the output becomes abnormal, you can assume that the trouble lies between this point and the last previous test point which resulted in normal output.

If the i-f section is good, inject a signal into the r-f section. Again using a modulated test signal, set both the receiver and signal generator to the same frequency in the broadcast band at some point between stations to prevent false indications. Inject the signal first at the r-f amplifier output (or converter input), and then at the antenna terminals. As before, abnormal sound output indicates a defect in the stage immediately following the test point.

Dynamic testing has the advantage that, with the fault isolated to a section or a single stage, further tests need be made in only this section or stage. You do not waste time making tests in circuits that are not defective. Also, dynamic testing checks the faulty unit under actual operating conditions. This is important because a stage may carry the proper dc currents, yet it may not be able to handle signals properly.

It is often difficult to feed test signals into low impedance transistor circuits from r-f generators with high impedance outputs. The amount of signal may not be strong enough to give a meaningful output indication. A coupling coil about 4″ in diameter consisting of about 25 to 50 turns of No. 20 hookup wire can be used to inject r-f signal into transistor gear. Just connect the signal generator output cable to the coil and place the coil close to the unit. This injects the signal into more than one stage at a time, but is useful in checking overall operation of the i-f and r-f sections.

Conversely, signals sometimes pass through a transistor stage even when the stage is not operating. This is because of the "feedthrough" characteristics of transistors. It takes experience with these circuits to avoid being confused by these actions. You can practice with a variety of receivers in good condition to learn what results to expect with normal circuits.

A type of generator called a noise generator or signal injector has been developed specifically for making injection tests. Generally, this consists of an RC oscillator, such as a multivibrator, that produces a fundamental frequency in the audio range. The waveform is such that the output contains harmonics that extend through the a-f, i-f and r-f ranges. Therefore, the output contains frequency components that can serve as test signals in any of the receiver circuits.

A signal injector has the advantage of speed because you can inject test signals at any point in the receiver without selecting test frequencies. Limitations are that it cannot be used for alignment and it often has a high impedance output which, as mentioned, makes injection somewhat difficult in transistor equipment.

This r-f generator can provide both amplitude- and frequency-modulated test signals for servicing both AM and FM receivers.

Courtesy Hickok Electrical Instrument Co.

Signal Tracing

Another dynamic testing method is called **SIGNAL TRACING**. With this method the test signal is the signal normally handled by the unit under test. With a radio receiver, you use the signal from a station or a signal generator. For a sound system, you can use the signal received by a tuner, or a signal produced by a phono pickup or tape playback head. The method consists of setting the unit to receive or accept one of these signals, connecting the signal source to the unit and touching the probe of an indicating instrument to various test points to determine the signal at each point. The indicating instrument may be an oscilloscope, an electronic ac voltmeter or a device called a signal tracer which is especially designed for this purpose. Again, practice with properly operating units is recommended to gain experience in what to expect in a normal unit.

Signal tracers are of two general types. One type is simply an audio amplifier with a detector probe. The other is a tuned radio-frequency (TRF) radio receiver. Both types employ speakers as indicators. Also, more elaborate testing devices are available. One such unit includes a receiver circuit for signal tracing as well as r-f and a-f generators for use in signal injection tests. Study the operating manual for the tracer carefully. As with other test instruments, it can be used with speed and success only when its operation is understood.

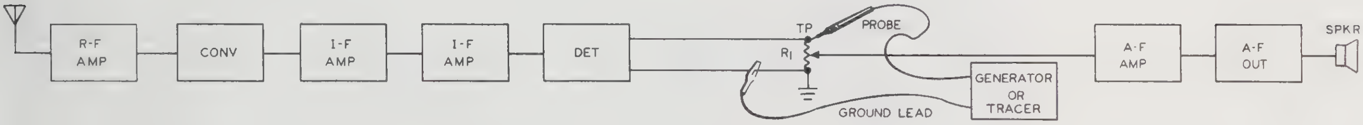


Figure 2

For convenience, Figure 1 has been duplicated and labeled as Figure 2. To illustrate the techniques of signal tracing, refer to the receiver of Figure 2. Connect the signal tracer ground lead to a ground point in the receiver. Set the receiver volume control to maximum. Tune the receiver to a station if any signals can be received. If not, touch the tracer probe to a test point in the front end of the receiver, and tune the receiver until the tracer indicates a signal is being received.

With the station tuned in, touch the tracer probe to the volume control, TP, in Figure 2. Because this section of the receiver follows the detector, a-f signals should be present at this point. Thus, an r-f detector is not required in the signal tracer to check the a-f section. As previously mentioned, this control is a convenient point at which to divide the receiver into two sections.

If a normal signal is produced in the tracer speaker with the test probe at this point, you can assume that the r-f and i-f sections are operating properly. The trouble is in the a-f section. Move the test probe to a point between the first a-f amplifier and the next stage. If a normal signal is not obtained, the trouble is in the first a-f amplifier. If the signal is normal, the trouble is in a following stage or the speaker.

Returning to the check at TP in Figure 2, if you do not find a normal signal here, the trouble is in the i-f or r-f sections. Begin at the antenna terminals and work toward the volume control, checking between successive stages as you go. When you reach a point at which the signal is not normal, the defect lies between this point and the previous point where the signal was normal.

Signal injection testing and signal tracing proceed in opposite directions. In general, with signal injection, you are seeking to learn how far ahead of the speaker the circuits are in good condition. You inject signals at successive points, moving from the speaker toward the front end of the receiver. In signal tracing, you are checking to see how far the received signal can travel through the receiver from the antenna before it reaches a defective circuit. You pick successive check points that move from the front end toward the speaker.

In dynamic testing, you must be sure that the test instrument is set properly for the section of the receiver you are testing. That is, for signal injection, the signal generator must be set to provide either an a-f or a modulated r-f or i-f signal, as needed. A signal tracer must be set to pick up either the carrier signal of the station being received, the i-f signal or an a-f signal.

An oscilloscope can be employed as the indicator in signal tracing. Using a low-capacitance test probe, you use the scope in the same general manner as described for other signal tracers. The main difference is that the indication is a visual pattern on the scope screen instead of sound from the tracer speaker.

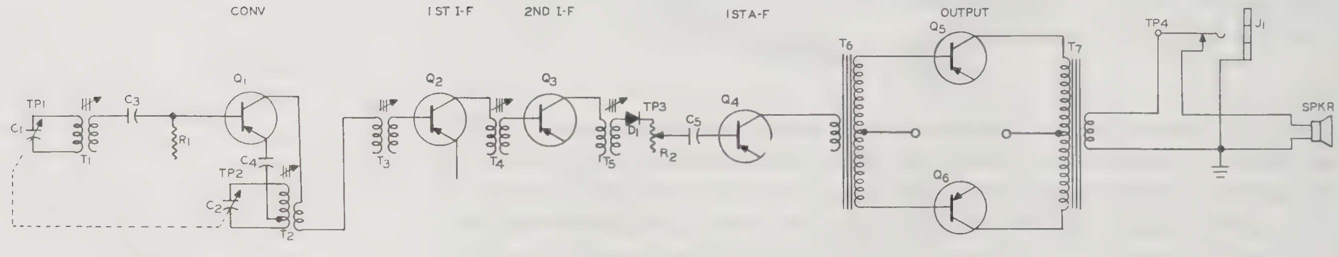


Figure 3

A partial diagram of a transistor receiver is shown in Figure 3. A number of commonly used test points are indicated as TP1, TP2, and so on. TP1 is the stator connection of tuning capacitor C_1 and the ungrounded end of the ferrite antenna, T_1. TP2 is the top end of oscillator coil T_2. TP3 is the top end of volume control R_2. TP4 is a terminal of the earphone jack. Other test points can be used, but these four yield a good amount of useful information.

Figure 4 shows a partial chassis layout of the circuit of Figure 3. The test points of Figure 3 are labeled in Figure 4.

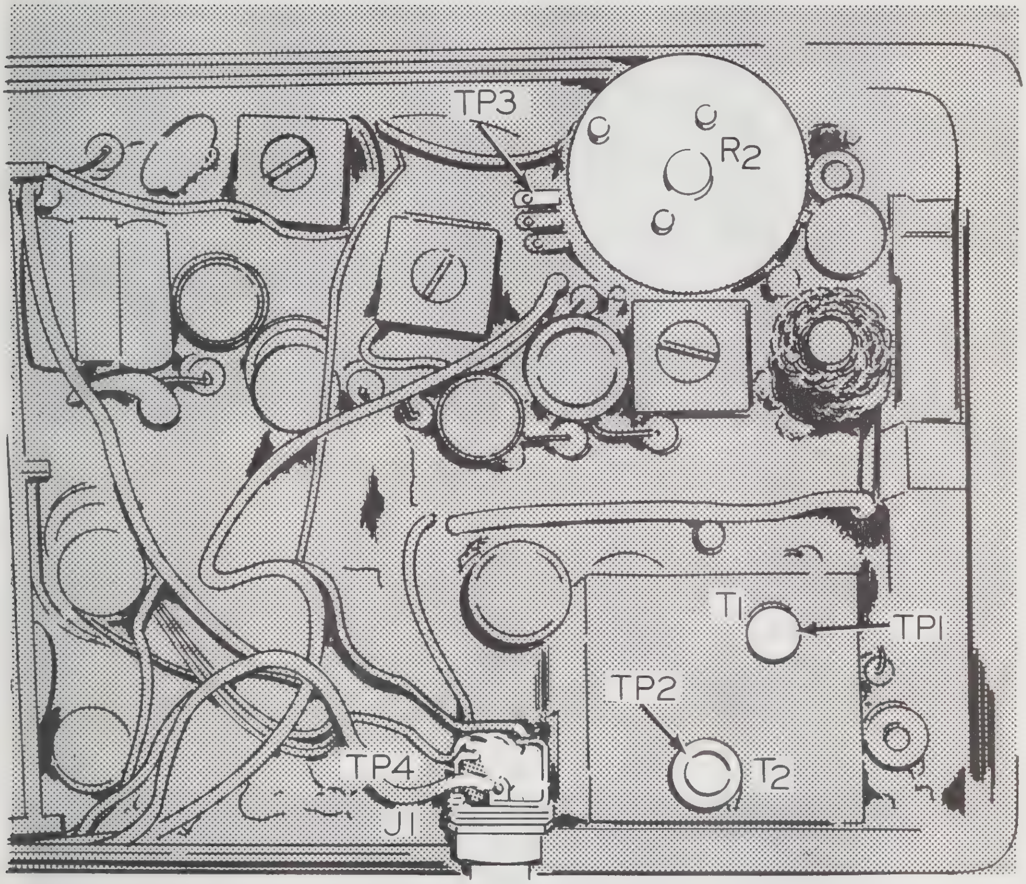


Figure 4

To check the signal at TP1 in Figures 3 and 4, rotate the receiver to the position that provides maximum pickup from the strongest local station. Set the tuning dial to a point slightly above the station frequency. This setting offsets the capacitance added by touching the test probe across the antenna tank. For stations around 1200 kHz, set the dial near 1400 kHz. For stations around 900 kHz, set the dial to about 1100 kHz. For stations with lower carrier frequencies, set the dial only slightly above the respective assigned frequencies.

With a scope ground lead connected to a convenient ground point in the receiver, and low-capacitance probe connected at TP1, the scope pattern displayed should resemble that of Figure 5. This is the modulated carrier wave and is obtained because the low-capacitance probe does not demodulate the carrier. A detector probe used here would show the pattern of the modulation signal. However, this signal is very weak at this point and would be very small and hard to see. It is the presence and strength of the carrier wave that is of interest here. Therefore, it is best to use the low-capacitance probe for this check.

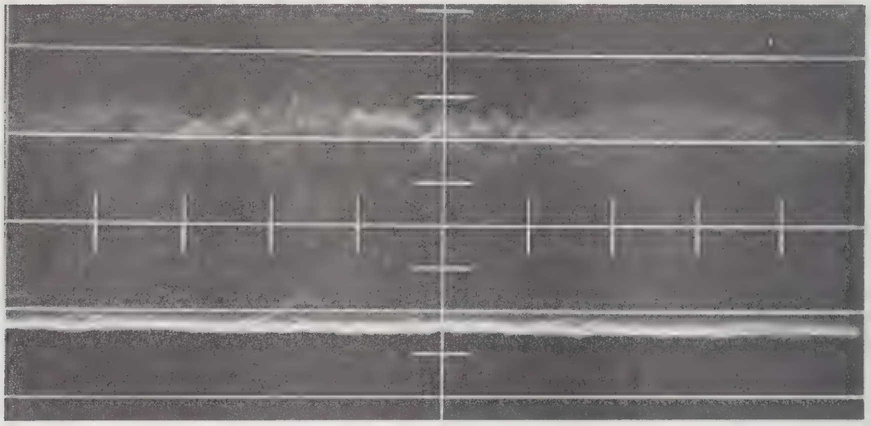


Figure 5

The normal signal amplitude at TP1 varies with receivers and station signal strengths. Typical values range between .1 and .3 volt peak-to-peak with small ferrite antennas, and up to about half a volt with larger antennas of this type. You can check various working receivers to set up standards for the area in which you are working.

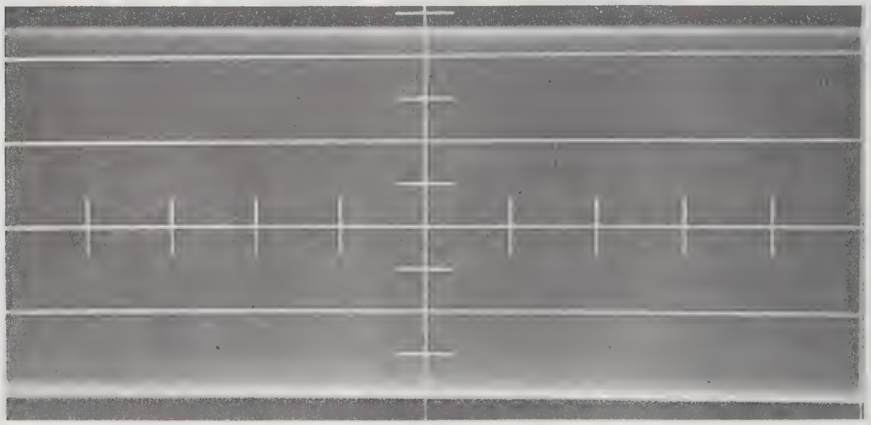


Figure 6

Touching the scope low-capacitance probe to TP2 should produce the pattern of Figure 6. Because this is the r-f voltage generated in oscillator tank T_2, it is not modulated. Typical amplitudes of this voltage range from about .8 to about 1.5 volts peak-to-peak. Small transistorized radios may produce oscillator outputs as low as .1 volt. If you increase the scope horizontal sweep frequency until it is approximately one-fifth that of the receiver oscillator, the pattern on the screen should have the general appearance of that shown in Figure 7.

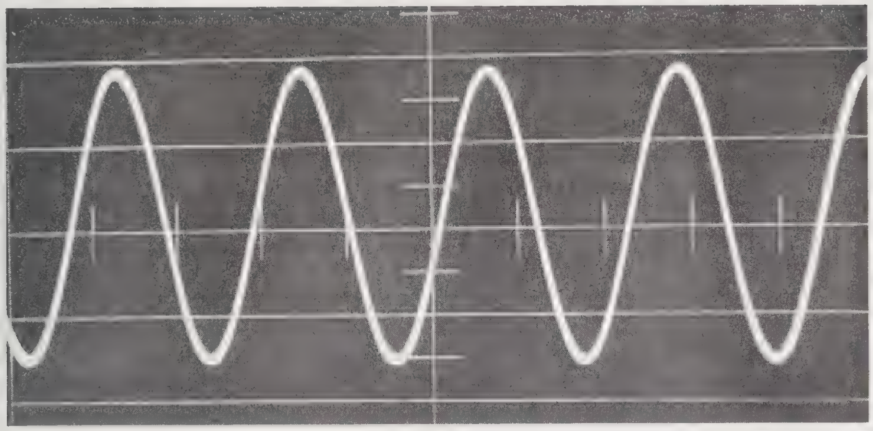


Figure 7

In a transistor radio, the waveform of the r-f voltage produced in the oscillator tank is important. Unless it is a pure sinewave, it may cause chirps and parasitic oscillations when the tuning dial is between stations and very near stations. Sometimes this is caused by a replacement converter transistor which has a higher gain than the original.

If the collectors of i-f amplifier transistors Q_2 and Q_3 are employed as test points, the scope patterns obtained should look like that of Figure 5. These are modulated i-f carrier signals. As before, check the amplitudes at these points in working receivers to set up standards.

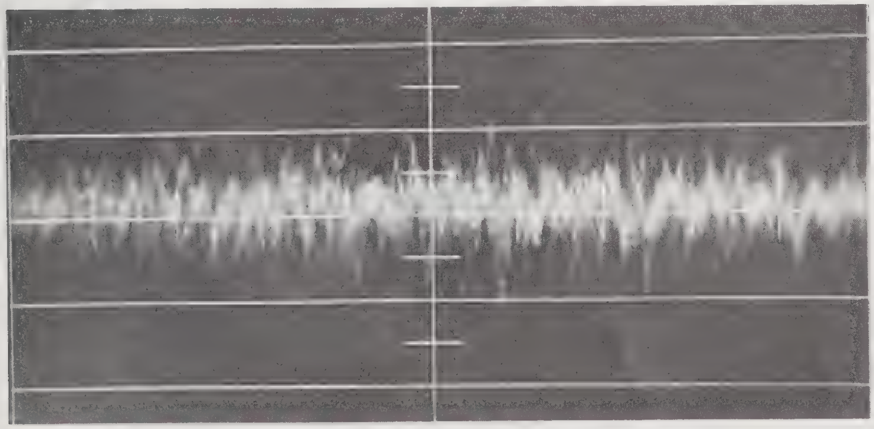


Figure 8

With the receiver positioned for maximum pickup of the strongest local station, touch the low-capacitance probe to TP3. The signal at this point is the demodulated output of detector D_1. Therefore, it should have the general appearance of Figure 8. Normal signal amplitudes at this point range from .3

to .5 volt peak-to-peak. If the signal is normal here, it indicates that the r-f and i-f circuits are operating properly.

The speaker and earphone jack are frequent sources of trouble in portable radio receivers. Indicated as TP4 in Figures 3 and 4, the earphone jack is an easily located test point. You can check both the jack and the speaker by touching your low-capacitance scope to this point. You should find a signal like that of Figure 8 with an amplitude of about 1 volt.

Voltage Testing

With no signal applied to the unit under test, voltages can be measured at various points in the circuit. This is a static testing method. The unit is turned on and because there is no signal input, the unit is said to be in a static condition. Generally, voltage tests are performed only in the section or stage indicated by dynamic tests to be faulty.

Manufacturers' service data and other service literature give the normal voltages at various points in the circuit with no signal applied. Most of these points are the transistor connections or tube socket lugs. You can check your voltmeter readings against these published values. Most defects cause the voltage to be abnormal at one or more points. Thus, any abnormal voltage you find leads you toward the defect.

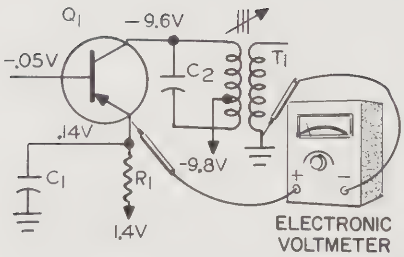


Figure 9

Figure 9 shows a voltmeter connected to measure the voltage between the emitter of transistor Q_1 and ground. The indicated voltages are the values given in the service manual of a typical radio receiver. In this example, the receiver power supply applies +1.4 volts to the lower end of R_1 and −9.8 volts to the tap on the T_1 primary, as indicated.

Under normal operating conditions, there is a voltage of 1.26 volts across emitter resistor R_1 in this circuit. The voltage at the emitter is $1.4 - 1.26$ or +.14 volt, as indicated. To measure this voltage, you would connect the positive meter prod to the emitter of Q_1 and the common or negative prod to ground, as shown. Service manuals usually state that all voltages are measured with respect to ground.

A very low meter range should be used to measure this low emitter voltage. However, make an initial check with a higher range. If Q_1 is conducting less-than-normal emitter current caused by some defect, the voltage across R_1 is reduced. The emitter potential is then nearer or equal to the potential at the source end of the emitter resistor. For instance, if there is no emitter current, there is no voltage across R_1. The emitter is then at the potential of the source, which is 1.4 volts in this example.

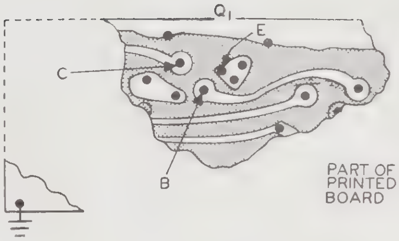
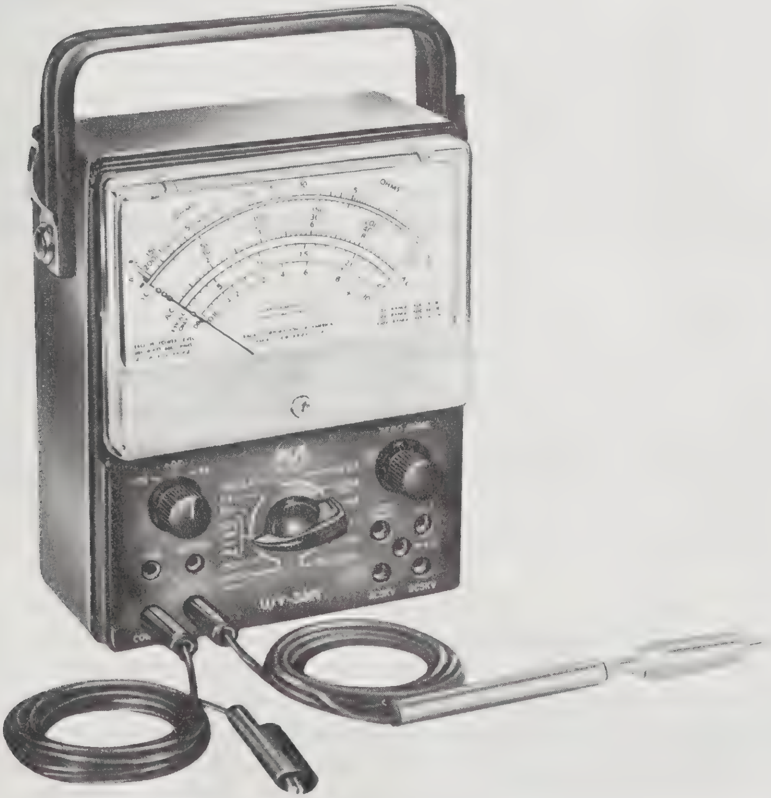


Figure 10

To help you locate the test points on a printed circuit board, most service manuals contain photos or drawings of the board with various points labeled. A part of the printed circuit board for the receiver that contains the circuit of Figure 9 is shown in Figure 10. Figure 10 shows the wiring side of the board, and labels C, B and E indicate the collector, base and emitter connection points of transistor Q_1. To measure the Q_1 emitter voltage, one meter prod is touched to point E and the other to the area indicated by the ground symbol in Figure 10.

As previously mentioned, a defect is indicated when a measured voltage is far above or below the value given in the service manual for that unit. The measured voltage is seldom exactly equal to the value in the manual. You must decide when it is too far off.



This portable volt-ohm-milliammeter is handy for service calls because it requires no outside power source.
Courtesy Radio Corporation of America

A service manual gives average values obtained by measuring the voltage at each point in a large number of units of the same model. These values are called nominal values. Almost always, the voltage at a given point in the unit you are troubleshooting will be a little higher or lower than the nominal value, even though the operation is perfectly normal. Unless otherwise stated, consider a measured voltage to be normal if it is within plus or minus 20% of the published nominal value.

Usually, the published values are based on a specified power line voltage, such as 117 volts, or a normal battery voltage. If a line or battery voltage, higher or lower, is applied to the receiver under test, you must make allowances for the resulting changes in the measured voltages.

Current Measurement

Measurement of the total battery current is often useful when troubleshooting transistorized units. It is made by placing a milliammeter in series with the battery. This measurement can be used to check the condition of the battery, and can often provide an indication of the overall condition of the receiver.

For example, if the total current is larger than normal, it is probable that a short exists in some circuit, or a transistor is drawing too much current. If the total current is less than normal, the current is probably too low or zero in some transistor.

Probably the most convenient means of measuring current in a portable transistor circuit is to use a dc power supply. Such a unit should have a variable voltage output (usually about 1-30 volts) and meters measuring voltage and current. Some units may use one meter that can be switch-selected for both current and voltage measurements. Current drawn by the circuit can now be conveniently measured, while proper voltage is maintained.

Generally, only the output stage in transistor equipment carries enough collector current to produce a noticeable change in total battery current when it is defective. To check for changes in the collector currents of other stages, Ohm's Law can be used because it is difficult to insert a current meter in series with the transistor. Emitter current will be measured indirectly because it is nearly the same as collector current. First, measure the voltage across the emitter resistor. Then, divide this value by the emitter resistance to obtain the current. The current value obtained is close enough for most purposes.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

BASIC TROUBLESHOOTING PROCEDURE

TESTING METHODS

SIGNAL INJECTION

SIGNAL TRACING

VOLTAGE TESTING

1. List the five major troubleshooting steps and the order in which they are performed.

2. Name the two types of dynamic tests.

3. Give three examples of static tests.

4. In Figure 1, an audio signal injected at the ungrounded end of the volume control does not produce a sound in the speaker. However, a signal injected at the input of the a-f output stage does produce a sound in the speaker. In what stage would you suspect trouble?

5. What type of signal is used for signal injection tests in the i-f section?

6. In Figure 1, a modulated r-f signal applied to the converter input produces an audible tone in the speaker, but there is no sound when the signal is applied to the input of the r-f amplifier. Where is the trouble likely to be found?

7. A dynamic test is often more reliable than a static test because it checks the faulty unit under operating conditions. True or False?

8. How does signal tracing differ from signal injection?

9. In signal tracing the receiver of Figure 2, if you do not receive a normal signal at TP, the trouble is probably in the audio amplifier. True or False?

10. In troubleshooting a radio receiver, signal tracing checks the circuits between the antenna and the test point, whereas signal substitution checks the circuits between the test point and the speaker. True or False?

11. Why is the receiver tuned slightly above the station frequency in making the signal test in the antenna circuit?

12. The scope pattern obtained in the oscillator tank circuit should contain the modulation of the incoming carrier signal. True or False?

13. The i-f signal of a receiver is a modulated wave. True or False?

14. A demodulator probe must be used to view the waveform at TP3 of Figure 3. True or False?

15. Why is it advisable to make preliminary voltage measurements on a higher voltage range, even though the manufacturer's service manual shows that the voltage at a given point is relatively low?

16. Unless otherwise stated, a measured voltage is considered normal if it is within 20% of the value specified by the manufacturer of the equipment. True or False?

This regulated power supply allows the user to observe circuit current drain.
Courtesy Heath Company

Using the circuit of Figure 9 as an example of indirect current measurement, assume that the measured voltage at the bottom end of R_1 is 1.35 volts, and that the Q_1 emitter is .15 volt. Also, assume that R_1 is a 1000-ohm resistor. To determine the voltage across R_1, subtract .15 from 1.35 to obtain the 1.2 volts. Divide this value by the resistance of R_1 to obtain the emitter current: $1.2 \div 1000 = .0012$ ampere or 1.2 mA. This is approximately the collector current.

Emitter and collector currents of around 1 mA are normal for transistor receiver stages other than the output stage. Some circuits contain a resistor in the collector circuit. You can then compute the collector current by dividing the voltage across this resistor by its resistance.

Like voltage testing, current measurement is a type of static test. Also, except for the check of the total current, most current tests are made only after a dynamic test has localized the fault to a section or a single stage. Current measurement is generally employed only when previous voltage tests have not shown definitely where the trouble is located.

Resistance Measurement

Dynamic tests indicate the faulty section or stage. Voltage tests isolate the trouble to a particular circuit in the faulty stage, and sometimes indicate a certain component as the cause of the trouble. However, a resistance test is often the only positive check of the suspected component.

Even when other tests have indicated quite definitely that a particular circuit component is defective, it is usually best to confirm your suspicions by making a resistance test before replacing the unit. This is necessary because many circuit components look good even when they are defective.

When you suspect that a component is shorted or open or has changed value radically, check the resistance of that component. Turn the power switch to the off position. Touch your ohmmeter test prods to the terminals of the component. Compare your resistance reading with the value given in the service manual. The reading should be within ±20% of the value listed in the manual.

Before making a measurement of this kind, check the circuit diagram to see if there are any paths in parallel with the component to be measured. Unless all such paths have a high resistance compared to that of the component under test, disconnect one lead of the component from the circuit. Measure the resistance with the component disconnected. If you then obtain an abnormal resistance reading, you can assume the component to be faulty.

In transistor circuits, the transistors often provide paths for ohmmeter current when the test prods are applied to measure other components in the circuit. When this condition exists, it is not possible to measure the resistance of the other component separately. Exceptions are those units in which the transistors are in sockets and can be removed for making resistance measurements. Transistors are usually wired into the circuit and cannot be removed unless you unsolder them. It is easier and better to disconnect a lead of the component you want to measure.

The service literature for transistorized units often does not list resistances from point to point as does the service literature for the tube equipment. This is because of the wide variations in the internal resistances of the transistors. In addition, you cannot measure the resistance in the circuit of one transistor electrode without including the parallel resistances of one or both circuits of the other two electrodes.

For tube equipment, the service manuals give resistance values that should be obtained when measuring from tube socket terminals to other specified points. For the cathode, control grid, suppressor grid, heater and diode plates, the resistance values are generally given from the tube socket lugs to ground. For the screen grid and plate, the resistances listed are often those from the socket lugs to the cathode of the rectifier in the power supply.

Except for the heater, the electrodes of a tube do not provide conductive paths through the tube. For example, with one ohmmeter test prod touched to the cathode socket lug, and the other to ground, only the resistance in the cathode circuit is measured. That is, unless it is shorted, a tube does not affect the resistances in the circuits of the various electrodes. Therefore, these resistances can be measured independently of each other.

If a resistance measurement results in an abnormally high reading, the suspected component is almost certainly the cause. However, before replacing it, check for high resistance connections between its leads and the points at which it connects into the circuit.

Conversely, if the resistance reading is abnormally low, the fault could lie in either the suspected component or a parallel path. Disconnect one of the component's leads and remeasure its resistance. Finally, when you have decided that a component is faulty and have removed it, give it a final out-of-circuit resistance check before you install a replacement part.

Continuity Testing

CONTINUITY TESTING is a variation of resistance measurement. As used here, continuity means a continuous or unbroken path for dc. That is, a circuit or component has continuity if it will conduct direct current. For example, a normal resistor, coil, connecting lead or soldered joint should have continuity.

An ohmmeter is generally used for continuity testing. However, you can use almost any source of direct current in series with some type of indicating device, such as a lamp. Touch the test leads to opposite ends of the component, circuit or connecting point to be checked. When making this type of test, you have little or no interest in the exact amount of resistance between the test points. The nature of the circuit between the points determines whether or not there should be continuity between them.

Part Substitution

Substitution of parts is another commonly used testing method. It consists of replacing a suspected component with one known to be good, and observing the results of the replacement. If the unit operates properly with the substitute part, it is logical to assume that the original is defective.

Tube or transistor checking by replacement is one form of this type of testing. Part substitution is not commonly referred to as either dynamic or static testing, but it can be used along with either procedure.

This substitution box is a handy addition to the service bench. Various values of resistors and capacitors can be substituted into a circuit during troubleshooting.
Courtesy Sencore Inc.

In some situations, a replacement part may be merely held so that its leads touch those of the suspected component. This places the two components in parallel. The good part is said to be "bridged" across the suspected part. With the suspected component thus bridged, you can turn the power on and observe whether or not there is an improvement in operation. If there is, the component you are bridging is defective.

Bridging is particularly useful in locating open components. Where it is not convenient or desirable to hold the bridging component in place, you can connect it temporarily by clipping or soldering it across the suspected unit. Always consider whether a shock hazard may exist by holding the component.

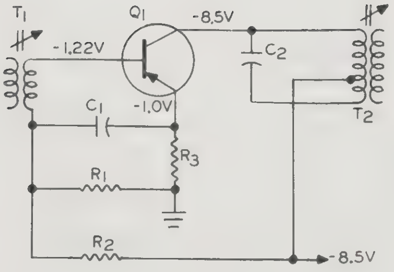


Figure 11

Open Connections

Sometimes useful information can be gained by simply opening the connection at one of the points at which a component connects to the circuit. Turn the power on with the connection opened, and observe whether or not the operation is improved. If it is, you can assume that the disconnected component is probably defective. For example, if operation improves after you disconnect one of the leads of capacitor C_1 in Figure 11, it is likely that this capacitor is leaky or completely shorted.

TROUBLESHOOTING IN THE FAULTY STAGE

Preliminary troubleshooting tests, often dynamic-type tests, isolate the trouble to a particular section or stage of the faulty unit. Further tests are required to find out which circuit in this stage contains the defect. Static tests of operating voltages are most useful here.

Figure 11 shows the second i-f amplifier stage of a typical broadcast radio receiver. The receiver is powered by a 9-volt battery, and the voltages indicated in this figure are the normal no-signal values. The positive terminal of the battery is grounded. In series with the negative terminal of the battery, a decoupling resistor drops the supply voltage to −8.5 volts.

In this stage, resistors R_1 and R_2 form a voltage divider, and their junction provides the potential of −1.22 volts to bias the base of Q_1. R_3 carries the emitter current, and the voltage across this resistor is 1 volt. This provides the emitter with a potential of −1 volt with respect to ground. Finally, the Q_1 collector has a normal potential of −8.5 volts, supplied through the upper portion of the T_2 primary winding.

Let's examine how the voltages in the circuit change when various defects occur. Assume that the circuit voltages change to those shown in Figure 12. In this example, both the emitter and base voltages are nearly zero. This condition results from an open in the base circuit such that the transistor base is no longer connected to the junction of R_1 and R_2. An open in the T_1 secondary winding would produce this condition.

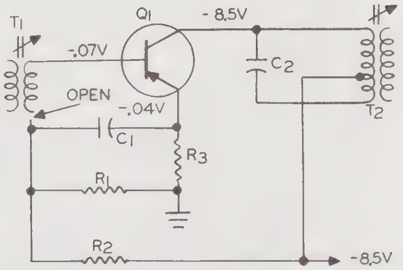


Figure 12

With the normal bias removed from the base, the regular conduction of the transistor is cut off. However, there is still a very small leakage current through Q_1 from collector to emitter. This leakage current results in a small voltage across R_3, amounting to .04 volt in this example. Also, a small voltage exists across the emitter junction. It makes the base .03 volt more negative than the emitter, and thus serves as a small forward bias. However, this self bias is so small that the transistor is considered to be cut off.

The base voltage change is not always as great as in Figure 12 when the base circuit opens. For example, Figure 13 shows another possible set of voltage conditions when there is an open between the Q_1 base and the source of normal base bias. The actual circuit defect is identical to that of Figure 12. However, as indicated in Figure 13, the base and emitter voltage decrease is not as great. The important fact is that they are BOTH lower than normal. In addition, the difference between the two is not as great as normal.

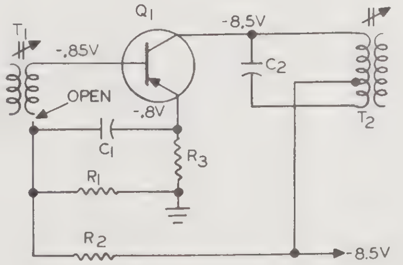


Figure 13

Other possible causes of abnormal voltage and current conditions are changes in resistance of R_1 or R_2, a partially shorted emitter junction in Q_1, and leakage in capacitor C_1. To check further, measure the voltage at the junction of R_1 and R_2. It should be about -1.22 volts in this example. If it is normal, yet the conditions of Figure 13 exist, you can be fairly certain that there is an open between this point and the Q_1 base, as indicated. If the voltage at the R_1R_2 junction is not normal, one of the other possible defects mentioned may exist.

The small differences between normal and abnormal voltages in these examples show that it is important to employ low ranges on your voltmeter and to read the meter scales carefully. In addition to the correct value, the base-emitter voltage must have the proper polarity for normal operation. With respect to the emitter, the base must be negative in a PNP transistor and positive in an NPN transistor.

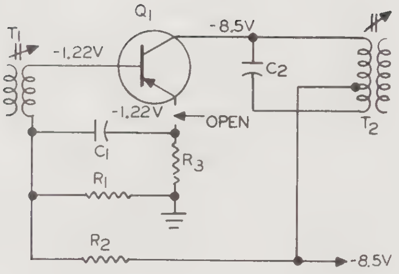


Figure 14

In Figure 14, the collector and base voltages have the normal values given in Figure 11, but the emitter potential has changed a small amount and now is the same as that of the base. In this example, the emitter has become more negative by $-.22$ volt, the amount of the normal base-emitter bias. This condition results from an open in the emitter circuit as indicated in the figure. This open disconnects the emitter from the external circuit so that, electrically, it is "floating." Inside the transistor, the emitter connects physically to the base. Therefore, the emitter assumes the potential of the base, as indicated.

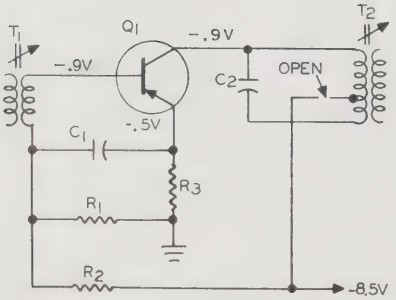


Figure 15

Figure 15 shows that a drastic change occurs in the collector voltage when the collector circuit opens. In this example, the collector voltage has changed from the normal value of -8.5 volts to the indicated $-.9$ volt. The base voltage is changed a small amount, and the emitter voltage is reduced to half its normal value in this example.

With the collector circuit open, there is no collector current. Therefore, the only current in emitter resistor R_3 is the base-emitter current. Normally, this current is very small. However, with reduced current in R_3, the voltage across this resistor reduces. This change makes the emitter less negative, thus increasing the forward bias between the base and emitter. As a result, base-emitter current increases somewhat. This increases the voltages across R_2 and R_3. The larger voltage across R_2 makes the base a little less negative than normal, as indicated. Also, the larger voltage across R_3 makes the emitter more negative than it would be if R_3 were carrying only the normal base-emitter current.

Thus, although the loss of collector current causes the base-emitter forward bias to increase as mentioned, this bias increase is limited by the opposing effect of the increased voltages across R_2 and R_3. As a result, the base and emitter voltages change until a stable condition is reached. In this example, the base voltage has reduced to −.9 volt and the emitter voltage to −.5 volt, as indicated. Because the collector is floating in this example, it assumes the potential of the base, and therefore is −.9 volt also.

In various circuits, the direction and amount of the change produced by an open depends on the circuit design. However, the same general actions are produced by each type of trouble. Thus, knowing what these actions are, you can determine the probable trouble by comparing your measured values with the normal values.

In general, you can suspect an open in the base circuit when the voltage across the emitter resistor indicates that the collector-emitter current is abnormally low with the collector voltage normal. The base potential may be anywhere from nearly normal to far from normal. An open in the emitter circuit is indicated when the base potential is normal but the emitter has the same potential as the base. Finally, an abnormally low collector voltage and a smaller-than-normal voltage across the emitter resistor indicates an open in the collector circuit.

The one voltage which becomes abnormal in every instance is the emitter voltage. Therefore, this voltage usually is one of the first to be checked in a faulty stage. As previously mentioned, the voltage across the emitter resistor is abnormally low if either the base or collector circuit is open. Here, you are concerned with the difference of potential between the two ends of the emitter resistor, whether one end of this resistor is grounded or not. When the emitter circuit is open, the emitter voltage is the same as the base voltage. In other words, there is no difference of potential between the emitter and base. Also, there is no voltage at all across the emitter resistor because emitter current is zero.

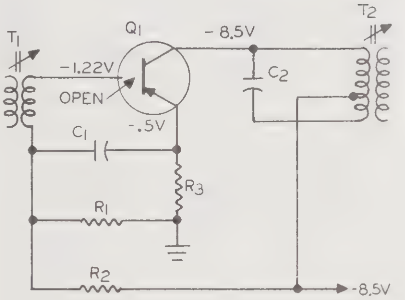


Figure 16

Usually, defects within a transistor cause voltages to change. For example, Figure 16 shows the results of an open base lead inside the transistor. As the external base circuit is not open, a "base voltage" measurement gives a normal reading. However, because of the open, the base current is zero. As a result, the only current in the collector and emitter circuits is the collector-emitter leakage current. Therefore, the voltage across emitter resistor R_3 is lower than normal. In the example of Figure 16 this change has reduced the potential at the emitter to −.5 volt, while the measured "base voltage" appears to be normal.

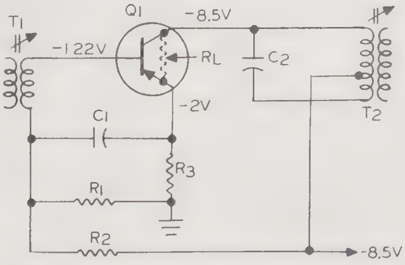


Figure 17

As another example, a typical change in the emitter voltage caused by a leaky transistor is shown in Figure 17. Here, R_L represents an undesired leakage path between the collector and emitter of Q_1. As this path shunts the transistor, the leakage current electrons move from the collector to the emitter without being affected by the transistor junctions. This current is also carried by the external collector and emitter circuits. It therefore increases the voltage across emitter resistor R_3.

Assume that the voltage change makes the emitter 2 volts negative with respect to ground, as shown in Figure 17. With this emitter potential, the base-emitter junction of Q_1 is reverse biased. Reverse bias on this junction normally cuts off the transistor. Because the measured emitter voltage indicates excessive emitter current instead of zero emitter current, you have reason to suspect a defect within the transistor.

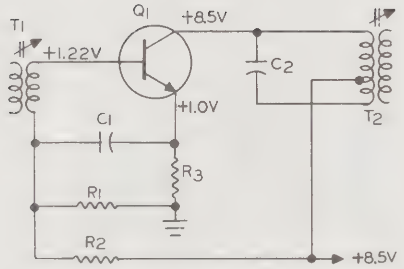


Figure 18

With the troubles shown in Figures 16 and 17, the measured base and collector voltages are normal. However, the trouble causes the emitter voltage to be abnormal in both examples, just as do all three of the open external circuits described previously.

In the circuit employed for these examples, the voltages are normal when they are reasonably near the values given in Figure 11. As previously mentioned, the battery has its positive terminal connected to ground in the typical receiver from which this circuit is taken. Therefore, as shown, the emitter, base and collector voltages are all negative with respect to ground. Also, when they are normal, the emitter voltage is the lowest, the base voltage is slightly greater, and the collector voltage is the highest.

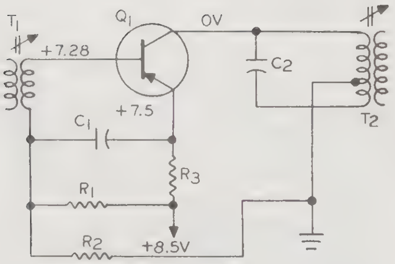


Figure 19

These three voltages can have the same order of magnitude when Q_1 is an NPN transistor, if the negative terminal of the battery is grounded. This arrangement is shown in Figure 18. Here, the supply voltage of +8.5 volts is obtained through a decoupling resistor that is connected to the positive terminal of the battery. As compared with the transistor voltages in Figure 11, those in Figure 18 have the opposite polarity, although their respective magnitudes are the same.

Figure 19 shows another commonly used circuit arrangement. Here, Q_1 is a PNP transistor, but the negative terminal of the receiver battery is grounded. This results in the transistor voltages having the reverse order of magnitude. That is, the emitter voltage is now the highest, the base voltage is slightly lower, and the collector voltage is the lowest (zero in this example).

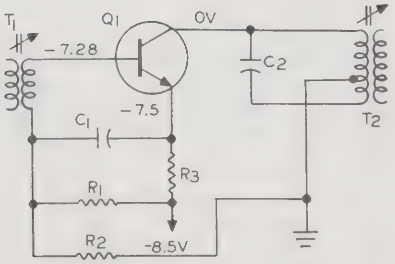


Figure 20

Figure 20 shows the same arrangement with an NPN transistor. In this circuit the positive terminal of the battery is grounded. Thus, the three transistor voltages have the same order of magnitude as in Figure 19, but opposite polarities.

Because all of these various circuit arrangements are in common use, it is important to check the voltage values and polarities given in the service manual for each make and model. If you do not have the data available, study the circuit carefully. Find which transistor elements return to ground, which battery terminal is grounded, and so on. An attempt to troubleshoot the circuit of Figure 19 by assuming the normal voltages of Figure 11, for example, would lead to confusion with regard to the cause of the trouble.

However, when you are aware of the normal voltage conditions in the unit you are servicing, the analysis used for the circuit of Figure 11 can be applied to any of the other circuit arrangements to find the cause of trouble. For example, a trouble that results in an abnormally low emitter current makes the voltage across the emitter resistor lower than normal, regardless of the transistor type or which terminal of the battery is connected to ground.

PRINTED CIRCUIT SERVICING

The most common construction method in modern electronic systems employs printed circuit boards for mounting and connecting circuit components. The nature of the printed boards makes it necessary to employ certain techniques to service the equipment in which they are used.

For example, on many boards, the components are mounted on one side while the copper foil connections between them are on the other side. In some instances, components are mounted on both sides. To find out how the components are connected, you must be able to locate the components and the connecting points. Also, you must be able to locate the various key test points in the circuit in order to troubleshoot the receiver or other faulty unit. This procedure was touched upon previously in connection with Figures 9 and 10.

As aids to troubleshooting, manufacturers' data usually include a schematic diagram and one or more pictorial views of the printed circuit board. These views identify each component and show its physical location on the board. They also show the copper foil connections between the components.

Figure 21 shows parts of two pictorial views. Figure 21A shows the component side of one end of a printed circuit board. As shown, the drawing has the wiring side superimposed on the component side. This shows how the board would appear if a light were placed underneath it. The wiring side of the same board is shown in Figure 21B. In this example, the components are superimposed on the wiring side. Their relative positions are reversed because the board is turned over.

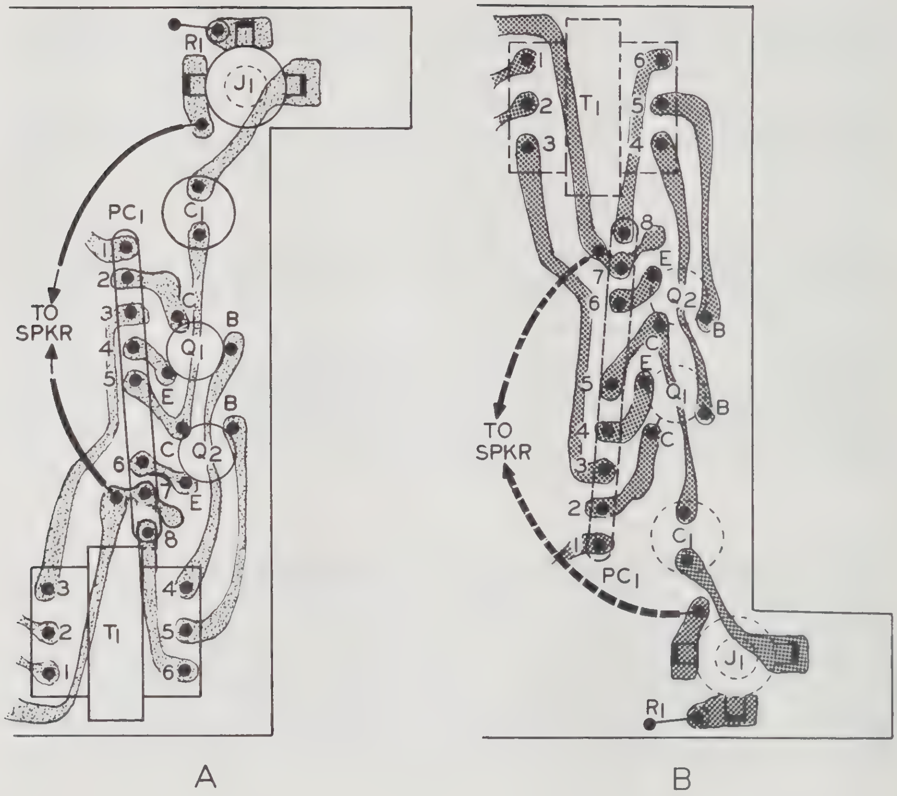


Figure 21

Figure 22 shows the schematic diagram of the section of the receiver shown in Figure 21. Corresponding component designations are used in the schematic and pictorial views. Figure 22 shows that the components in Figure 21 make up the audio output stage.

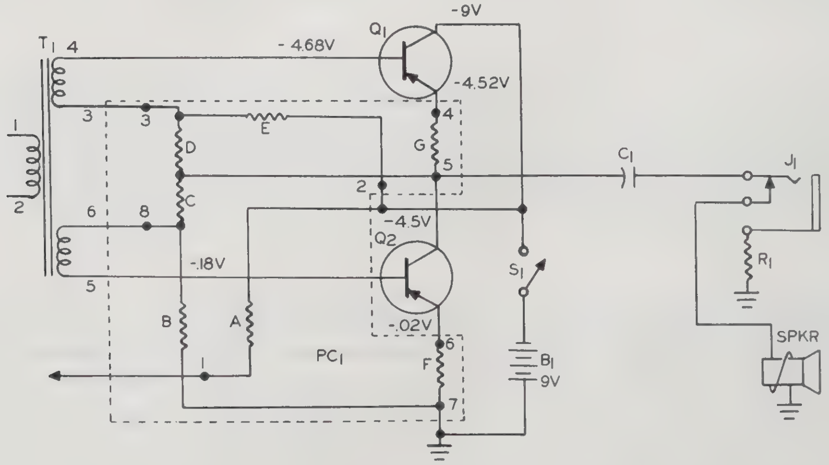


Figure 22

The following Practice Exercise questions cover the subjects which you have just studied. They are:

TESTING METHODS

- CURRENT MEASUREMENT
- RESISTANCE MEASUREMENT
- CONTINUITY TESTING
- PART SUBSTITUTION
- OPEN CONNECTIONS

TROUBLESHOOTING IN THE FAULTY STAGE

17. How can you measure current without breaking into the circuit?

18. At what point in the troubleshooting sequence would you perform current measurements, assuming they are necessary?

19. Resistance measurements are made with the circuit power (a) on, (b) off.

20. Why is it often necessary to disconnect one end of a component from the circuit before measuring the resistance of the component?

21. You are troubleshooting the circuit of Figure 9, and you get a very low resistance when you connect an ohmmeter across C_2. Does this indicate a defect in C_2, and how can you check further to verify the condition of this capacitor?

22. What is the purpose of continuity testing?

23. An ohmmeter shows zero resistance between the ungrounded end of C_1 and the junction of R_1 in Figure 9, but infinite resistance between this junction and the emitter lead of Q_1. What can you conclude from this test?

24. In troubleshooting the circuit of Figure 9, bridging a good capacitor across C_1 causes the circuit to function normally. The probable trouble is (a) a short in C_1, (b) an open in C_1.

25. When the base potential of a transistor is normal, but the emitter is at the same potential as the base, the trouble is likely to be an open in the (a) emitter circuit, (b) base circuit, (c) collector circuit.

26. In troubleshooting a defective transistor stage, it is a good idea to make the first voltage test at the (a) base, (b) collector, (c) emitter.

27. Compare the voltages in the NPN transistor circuits of Figures 18 and 20. Although the grounding arrangement is different in these two circuits, explain how the voltages on the emitter, base and collector are related to each other.

For example, in the schematic diagram, T_1 is the interstage audio transformer. This unit is shown at the bottom in Figure 21A and at the top in Figure 21B.

Figure 22 shows that the base of Q_1 connects to one secondary of T_1 at terminal 4, and the base of Q_2 connects to the other secondary at terminal 5. Figures 21A and 21B both show these connections between terminals 4 and 5 of T_1 to the respective bases of Q_1 and Q_2.

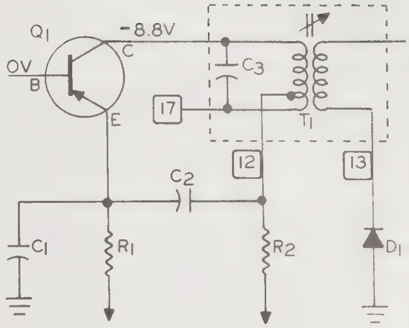


Figure 23

Similar comparisons between Figures 21 and 22 show how the other connections are made in this stage. The unit labeled PC_1 is a packaged circuit. It is made up of the seven resistors labeled A through G in Figure 22. Inside the unit, these resistors are connected as shown in the schematic. External circuit connections are made to the points numbered 1 through 8.

In some diagrams, key test points in the circuit are designated in the pictorial and schematic diagrams of the unit. As an example, Figure 23 shows the schematic diagram of the second i-f amplifier stage in a radio receiver. Three key test points are indicated by the boxed numbers 12, 13 and 17. Other test points commonly used are the collector, base and emitter of transistor Q_1, labeled C, B and E in the diagram. Figure 24 shows the corner of the printed board in which these test points are located. The six test points are indicated by the same numbers and letters used in the schematic.

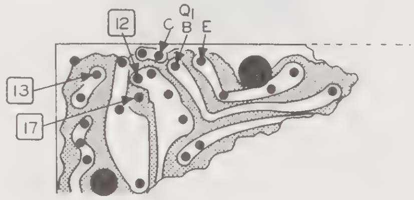


Figure 24

This AM/FM stereo receiver employs modular construction. The various individual circuits are mounted on individual printed circuit boards which, in turn, mount on a main circuit board. A defective sub-assembly can be simply replaced with a new one.

Courtesy Electron-Voice

Thus, the diagrams provide well-marked "road maps" for the serviceman. By using the photos or drawings of the printed boards along with the schematic diagrams, you can locate the various components and test points on the boards you are servicing. Usually, most of the components in a given stage are located near each other physically. This fact is helpful in tracing a printed circuit.

Often, the printed circuit board is made of a material which permits light to shine through it. A common troubleshooting practice is to direct a light against one side of the board while viewing the other side. This makes the board look like the pictorial drawings of Figures 21 and 24. Using light in this way, you can locate junctions on either side of the board. View the component side and hold a soldering aid on the other side so that its shadow is cast onto the board. Move the tip of the soldering aid to the desired junction, and hold it there against the board while you move around so you can look at the wiring side to locate the junction.

With boards of the type shown in Figures 21 and 24, you can usually make troubleshooting tests by touching your test prods to component junctions or conductors on either side of the board. Needle point test prods are needed to penetrate the protective coating of lacquer or varnish that is sprayed on during the manufacture of the printed board.

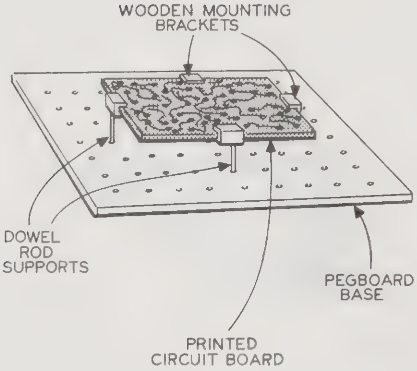


Figure 25

During troubleshooting, the board should be held in a support so that both of your hands are free. If you use a vise, be careful not to tighten it too much. The vise should only hold the printed board, not crush it. You can use a homemade jig such as that shown in Figure 25 to hold the board. Here, the board is held in brackets supported by dowel rods which are stuck into holes in a pegboard base. Commercial jigs are also available.

INTEGRATED CIRCUIT SERVICING

It is often easier to troubleshoot radio receivers and other equipment containing integrated circuits than units made up entirely of discrete (conventional) components. The reason for this is that, when an integrated circuit fails, its operation usually changes radically or ceases completely. Therefore, when it is checked, the test results generally leave little doubt as to whether the circuit is good or bad.

Conversely, it is common for discrete components to change gradually with age. A group of such components changing in this way often causes the operation of a circuit to degrade slowly. Eventually, the operation becomes poor enough to be noticeable. However, after you have made a number of troubleshooting tests, it is sometimes difficult to determine exactly which component is the main cause of the trouble. Transients or excessive voltages can damage or destroy transistors or integrated circuits.

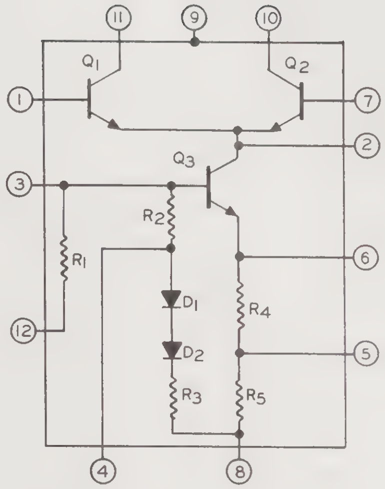


Figure 26

Figure 26 shows the schematic diagram on one type of integrated circuit used in radio receivers. As shown, it includes three transistors, two diodes and five resistors. Used along with external tuned circuits, capacitors and resistors, it can be employed as an r-f amplifier, a mixer-oscillator, or both, or as an i-f amplifier.

Another typical integrated circuit is shown in Figure 27. This unit contains twelve transistors, twelve diodes and thirteen resistors. Along with external components connected to its various terminals, it is capable of performing several of the functions required by a radio receiver. For example, transistors Q_1 through Q_6 with resistors R_1 through R_7 provide i-f amplification. Transistors Q_7 and Q_8 with resistor R_8 serve as an i-f limiter. An internal power supply circuit is made up of transistors Q_9 and Q_{10}, resistor R_{10} and diodes D_1 through D_7. The remaining diodes along with resistors R_{11} and R_{12} make up most of an FM detector circuit. Finally, low-level audio-frequency amplification is provided by transistors Q_{11} and Q_{12} and resistor R_{13}. The audio output of this stage is taken from terminal 9, and applied to an external audio output stage.

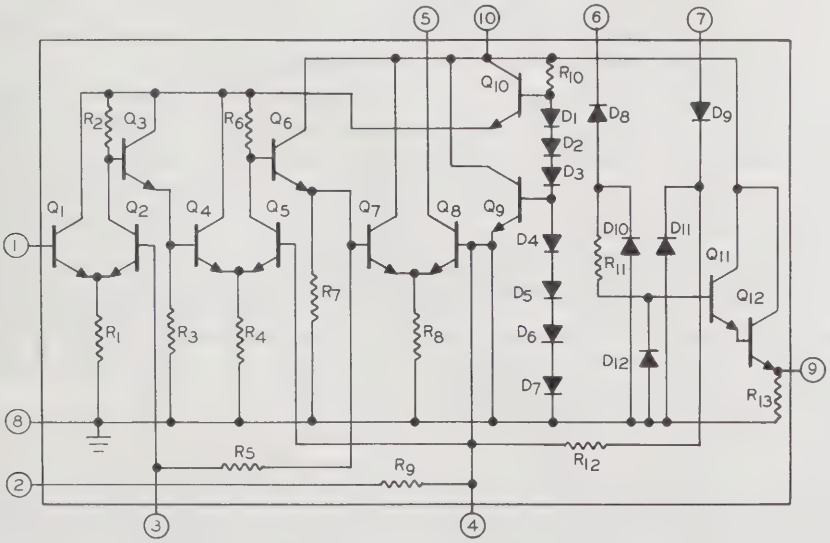


Figure 27

Both of the above types of integrated circuits are employed in an FM broadcast radio receiver, the diagram of which is shown in Figure 28. Except for the audio output stage, this diagram includes the complete circuit of the receiver.

Designated IC_1 through IC_4, four integrated circuits are employed. As shown, besides the integrated circuits, the receiver contains only a small number of discrete circuit components, as compared with receivers employing other construction methods.

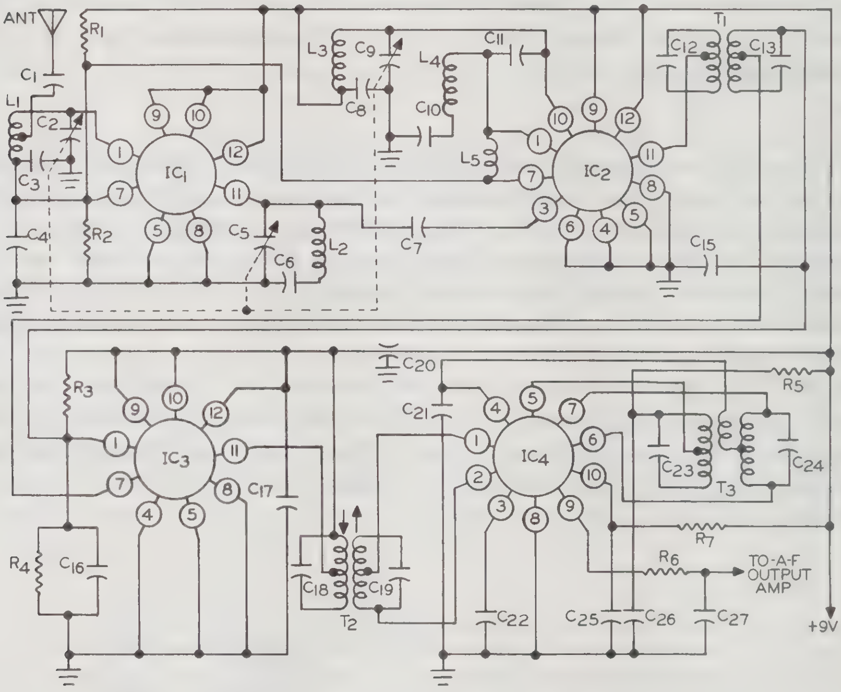


Figure 28

In the receiver of Figure 28, integrated circuits IC_1, IC_2 and IC_3 are all of the type shown in Figure 26. IC_1 is the r-f amplifier. IC_2 operates as the mixer-oscillator. IC_3 serves as an i-f amplifier and limiter. IC_4 is the type shown in Figure 27. It provides the functions of i-f amplifier, limiter, detector and first audio stage.

The basic troubleshooting procedure outlined at the beginning of this lesson can be applied to receivers of this type as well as to other types. After you complete your preliminary inspection, employ signal injection or signal tracing to isolate the trouble to a section or stage.

In the receiver of Figure 28, for example, the output of the first audio stage can be checked at terminal 9 of IC_4. The input to this integrated circuit is applied to terminals 1 and 2. Terminal 11 of IC_3 is the output of this stage, while the input is applied to terminals 1 and 7. The output of the r-f amplifier can be checked at terminal 11 of IC_1. It should be present at terminal 3 of IC_2. The r-f voltage across oscillator tank L_3C_9 can be checked at terminal 10 of IC_2, and so on.

If a received or injected signal does not pass through an integrated circuit, or is abnormal at the output terminals of the circuit, you can suspect that the trouble is in the integrated circuit. Check the dc voltages at the pin terminals of the integrated circuit. Normal voltage values for each terminal are given in the service manuals.

Before deciding definitely that the integrated circuit is at fault, check all of the external components that could cause the abnormal condition. If all such components appear to be normal, and all your tests have indicated that the trouble could be within the integrated circuit, check further by replacement with a new unit of the exact same type. Carefully remove the old unit and install a new unit, making sure that you do not damage the printed circuit board.

TRANSISTOR TESTING

Earlier in this lesson, we mentioned that transistors are usually suspected only after checks have indicated the other components to be in good condition. In equipment employing integrated circuits, all or most of the transistors are included in the integrated circuit structure. As previously mentioned, if one of these circuits is found to be defective, the entire unit must be replaced. It is of very little interest to the troubleshooter whether a transistor or other component inside the integrated circuit is the actual cause of the trouble.

Often, however, the unit employs one or more transistors that are not inside an integrated circuit. In this equipment, as well as that which does not employ integrated circuits, the transistors are possible suspects when checks of the other components do not locate the defects. In the event another test seems to indicate that a given transistor is the cause of the trouble, you can check this transistor immediately. In such instances, you do not have to wait until all of the other components have been checked. However, to avoid possible waste of time, this check should be an "in-circuit" test if possible. An in-circuit test is one in which the suspected component is not disconnected or removed from its circuit for testing. When a component is removed for testing, the check is called an "out-of-circuit" test.

In-Circuit Tests

Certain facts about the electrical condition of a transistor can be learned without removing the transistor from the circuit. This saves troubleshooting time because the transistor leads are often soldered into the circuit. In-circuit checks can be made several ways. Commercial in-circuit transistor testers are available. With these, test leads are simply clamped onto the leads of the transistor to be checked, without disconnecting it from the circuit. One tester of this type employs a bridge circuit, of which one arm is formed by the input circuit elements of the transistor under test. Control panel adjustments remove the effect of these elements so that the gain of the transistor can be measured as though the transistor were out of the circuit.

Indications of transistor condition can be obtained by making in-circuit checks with an ohmmeter. Remember that a transistor may be considered as two diodes connected back to back. We refer to the two junctions as the "emitter diode" and the "collector diode." Each of these junctions presents much greater resistance to current in one direction than in the other. You can check this difference in resistance with your ohmmeter with the transistor in its circuit.

The best range to use with your particular meter will be found easily by experience. Generally speaking, it may be best to start with the R × 100 range and switch to a lower range when necessary. However, on the R × 1 range, many ohmmeters have a resistance of only 15 ohms in series with the battery. Where the transistor junction resistances are very low, this meter range may produce a current large enough to damage the transistor. Also, on the R × 10,000 and higher ranges, some ohmmeters switch in a 22.5-volt battery. This may prove harmful to a transistor if the resultant voltage across a junction is higher than the transistor's voltage rating.

As a general rule, do not use the R × 1 range on low-power transistors. These are the transistors used in the r-f, converter and i-f stages of a radio. Also, do not use the R × 10,000 range on any transistors.

To perform the transistor "diode" test, turn the unit off and set your ohmmeter to the R × 100 range. Touch the test prods to the base and collector, as shown by meter M_1 in Figure 29. Observe the resistance reading. Reverse the test prods. Measure the collector junction resistance again. One of these readings should be much higher than the other. Usually, it is from 5 to 10 times the value of the lower reading if the transistor is in good condition. If both readings are too low on the scale to compare easily, switch to lower meter ranges until the higher reading is about mid-scale.

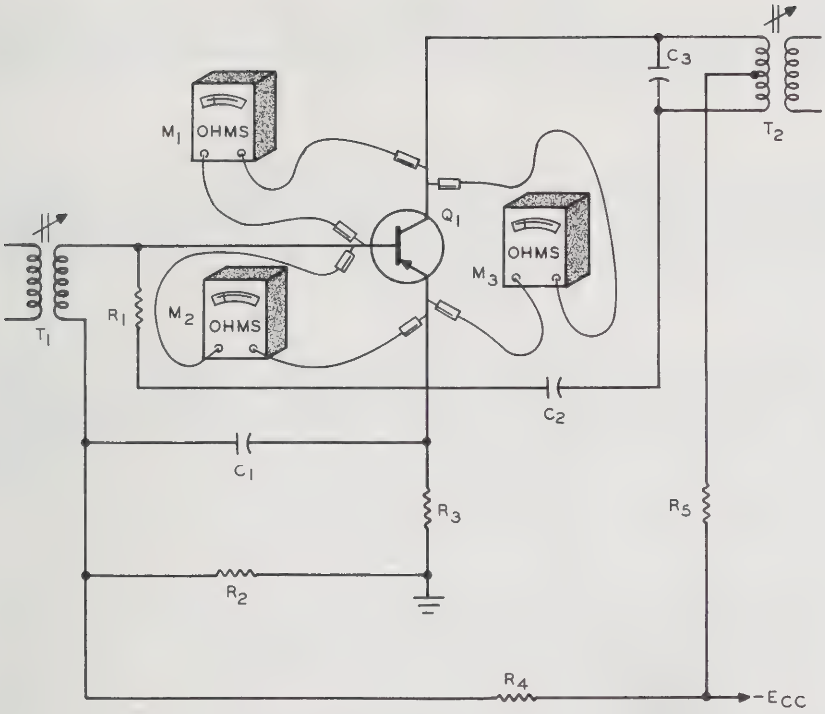


Figure 29

The difference between the higher and lower readings is not as great with the transistor in the circuit as it would be if the transistor were removed from the circuit. The reason is that the transistor junctions are shunted by the external circuits. In Figure 29, one such circuit is the path from the Q_1 base through the T_1 secondary, through resistors R_4 and R_5, and through part of the T_2 primary to the Q_1 collector.

To check the emitter junction, touch the test prods to the base and emitter, as shown by meter M_2. Observe the reading, reverse the prods, and measure again. Again, one reading will be much higher than the other if the transistor is in good condition. This junction is shunted by the T_1 secondary and R_2 and R_3 in series.

Although a PNP transistor is shown in Figure 29, exactly the same procedure can be used with NPN types. With either type, the junction resistance normally is lowest when the meter battery voltage forward biases the junction, and highest when this voltage applies reverse bias.

In the base of medium-power transistors such as those in the a-f driver stages, you can use the R × 1 range if higher ranges make the meter read too near the low end of the scale. This low range can be used with a-f amplifier-type transistors because they are able to carry larger currents without being damaged.

Generally, no difference in the resistance readings is obtained in the diode or junction resistance test if one of the element leads is open inside the transistor. In this situation, the reading is equal to the circuit shunt resistance in both positions of the test leads.

When high-power transistors fail, they usually short out completely between the collector and emitter. Therefore, measurements of the junction resistances are seldom made for the power output transistors. When they are made, the very low circuit resistances result in low resistance readings in both positions of the test prods. To measure the junction resistances on power transistors, it is often necessary to use the R × 1 meter range.

A third in-circuit test that you can make with your ohmmeter is a check of the collector-to-emitter leakage resistance. You perform this test by connecting the meter as shown by M_3 in Figure 29. For the most part, this test is useful for checking high-power transistors like those used in output stages. As previously mentioned, these units usually short completely when they fail. If the transistor is in good condition, the ohmmeter indicates a low resistance. This reading is obtained because the shunting circuits in high-power stages contain only low resistance. However, if the transistor is shorted, the reading will be zero.

A completely shorted condition is rare in transistors that are not high-power types. Instead, they open or merely become leaky between the collector and emitter. The leakage resistance is often about the same magnitude as the shunting circuit resistances. Therefore, with these transistors, an in-circuit collector-emitter leakage test is not very helpful. The shunting circuit resistances affect the reading a considerable amount, and in doing so can easily cause a good transistor to appear abnormally leaky. Thus, to make a collector-emitter leakage test on any transistor other than a high-power type, it is best to remove the transistor from the circuit.

Out-of-Circuit Tests

When any of the in-circuit tests indicate a transistor to be faulty, remove it from the circuit for further testing. In this way, you can make certain that the transistor is actually the faulty unit before you replace it. The removal may be complete or only partial, depending on the testing method to be used. If the transistors are mounted in sockets in the unit being repaired, you can remove them easily for checking. In fact, when the transistors are mounted in sockets, it may be faster to omit the in-circuit tests and simply make out-of-circuit tests.

Out-of-circuit transistor testing may be performed in a number of ways. Use of a reliable transistor tester is probably the most positive way of checking, except for substitution with a unit known to be good. The transistor tester should either permit you to check the characteristics of the unit, or it should provide a test circuit that shows whether or not the transistor can operate normally. Other testers make a rough "gain check," or permit you to compare the forward and reverse resistances of the junctions, as explained. Although they may be more convenient, these simpler testers give no more information than you obtain by using an ohmmeter in the manner to be explained.

It is possible that a transistor may short while operating under normal circuit voltages and still show "good" on a (lower voltage) tester. Substitution is the most practical way of isolating this problem.

Generally, a normal transistor continues to operate with essentially the same gain and high-frequency cutoff characteristics for the useful life of the equipment in which it is employed. Most often, when a transistor fails, the failure takes the form of a short or an internal open which prevents normal operation completely. Thus, the transistor either operates normally or it doesn't operate at all. Therefore, in general service work, it seldom becomes necessary to measure the gain or other operating characteristics of the transistor.

Based on these facts, a testing method has been worked out by one manufacturer which checks the ability of a transistor to perform its required functions in a typical circuit, without making separate measurements of gain and other characteristics. This tester places the transistor in a test audio oscillator circuit. The output indicator is a speaker. When the tester's C, B and E leads are clamped onto the collector, base and emitter leads, respectively, of a transistor, the transistor becomes the "active" component of the test oscillator circuit.

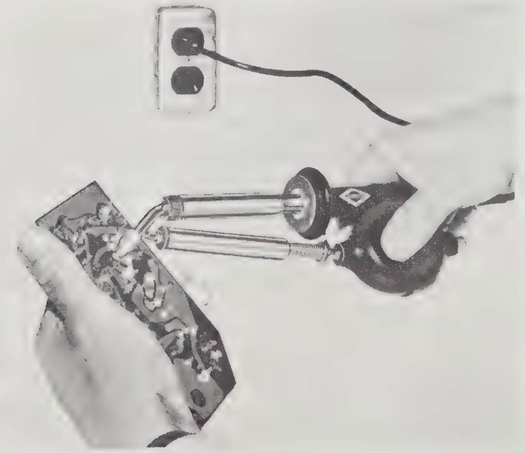
With this tester, a normal transistor will produce oscillation which is indicated by an audible tone in the speaker. A regeneration control can be turned to reduce the feedback until oscillation stops. The control setting at which oscillation stops gives a rough indication of the gain of the transistor. A transistor that will not produce the audible tone at any setting of the regeneration control is defective.

In most equipment, transistors are soldered into the circuit. These units can be removed only by unsoldering their leads from the circuit. Do this very carefully so you do not damage the printed circuit board in any way.

In unsoldering a transistor from a printed circuit board, you are usually faced with the problem of unsoldering all three leads at the same time. One way to do this is to remove the solder from each connection with a desoldering aid. One such aid removes the molten solder by vacuuming it into a bulb.

With the transistor removed from the circuit, check the collector junction resistance by touching your ohmmeter prods to the collector and base leads as in Figure 29. Then, as before, reverse the prods and measure again. The difference between the two resistance readings should be much greater than it is for an in-circuit test. Repeat the procedure, using the base and emitter leads, to compare the forward and back resistances of the emitter junction. Again, the difference between the two readings should be much greater than in an in-circuit test.

On the R × 100 range of the meter, the back resistance of the junctions may appear to be nearly infinite. The forward resistances are usually less than 1500 ohms. Should one of the element leads be open inside the transistor, the reading is infinite resistance with both positions of the test prods. An internal short will result in a low resistance in both directions.



This soldering iron includes a desoldering attachment which can be used to remove solder from a pc board, simplifying component removal.

Courtesy Enterprise Development Corp.

In the same manner, you can check the collector-to-emitter leakage resistance of low-power type transistors. The resistance reading should be high with either position of the test prods. For low-power r-f and i-f transistors, the leakage resistance should be greater than 5000 ohms. For the medium-power a-f units, a reading of over 500 ohms should be obtained. Normal high-power transistors have a collector-to-emitter leakage resistance of more than 100 ohms.

Substitution

The most reliable type of transistor test is substitution with a unit known to be good. The ideal substitute is a transistor of the exact type to be checked. However, it is nearly impossible for a service shop to stock all of the many types in use. The next best substitute is another type that is practically the same as the unit to be checked. Keep a good transistor substitution guide on hand to help you find substitutes of this kind quickly.

Unsolder the suspected transistor from the printed board and solder the substitute in its place only if you find this to be absolutely necessary. If the substitute does not clear up the trouble, indicating the fault to be elsewhere, you may have to resolder the original unit back into place before proceeding with further tests.

Figure 30 shows a method of performing a substitution check without unsoldering the original transistor from the board. On the printed wiring side of the board, use a knife or razor blade to cut slits in any two of the three printed conductors that connect to the transistor terminals. Before cutting the slit, scrape the lacquer coating from the conductor in the area where the slit is going to be made, as shown in Figure 31A. This makes it easier to repair the conductor later.

With the slits cut, solder the leads of the test transistor to the three conductors as shown in Figure 30. Notice that when the two conductors are slit, the test transistor leads are connected on the side of the slits away from the side that the original transistor is connected. The test transistor is now in the circuit in place of the original transistor, although the original transistor is still soldered to its connection points on the board. When soldering the test transistor to the conductors in this way, use a minimum of solder. This process is called "spotting" or "tacking," and is useful for making substitution checks of other components also.

With the test unit in place, turn on the power. If the trouble is cleared up, a replacement is needed. Remove both the test transistor and the original

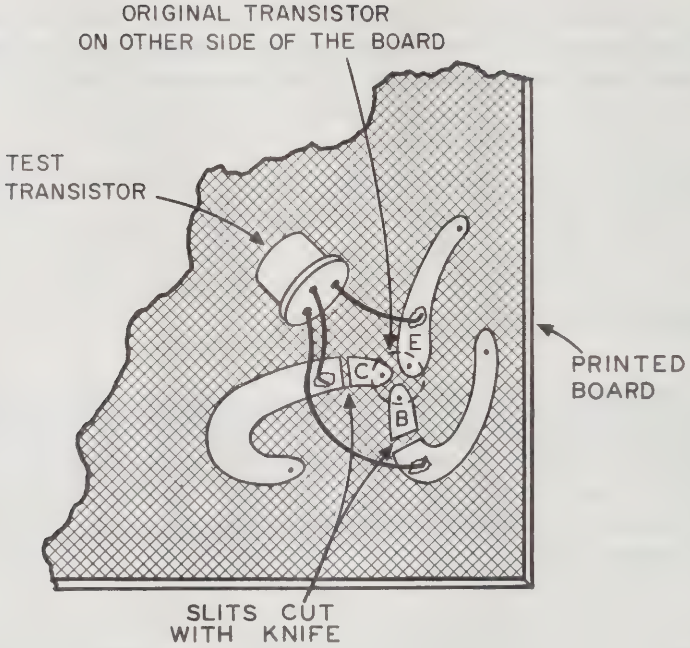


Figure 30

transistor. Repair the slit conductors, and solder a replacement transistor to the points to which the original unit was connected.

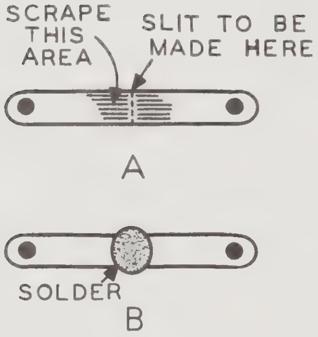


Figure 31

The slits can be repaired by applying a drop of solder across them, as in Figure 31B. You can also place a short length of jumper wire across the slit before soldering.

Provided suitable substitutes are available, transistor substitution testing is very easy when the radio receiver or other unit has its transistors mounted in sockets. In these instances, you may find it desirable to check some of the transistors at an earlier point in the troubleshooting procedure when the troubles are types that are frequently caused by faulty transistors.

SUMMARY

The troubleshooting procedure employed by most service technicians can be broken down into five basic steps:

1. Determine the symptom.
2. Make initial checks.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

PRINTED CIRCUIT SERVICING

INTEGRATED CIRCUIT SERVICING

TRANSISTOR TESTING

IN-CIRCUIT TESTS

OUT-OF-CIRCUIT TESTS

SUBSTITUTION

28. What does the dashed line around part of the circuit in Figure 22 indicate?

29. What is the purpose of the numbered squares in the schematic diagram of Figure 23 and the pictorial diagram of Figure 24?

30. How can a light help you in tracing the circuits on a printed board?

31. It is usually far more difficult to troubleshoot radio receivers containing integrated circuits than receivers made up entirely of discrete components. True or False?

32. An integrated circuit contains a number of stages in a sealed unit. How is it possible to apply standard test methods to this type?

33. When you suspect a transistor of being defective, an (a) in-circuit test is desirable, (b) out-of-circuit test is desirable.

34. The principal reason for using an in-circuit transistor is to save time. True or False?

35. Why is the choice of range important when using an ohmmeter for an in-circuit transistor test?

36. Briefly describe the method of testing a transistor collector junction with an ohmmeter.

37. When performing an in-circuit test of collector-to-emitter leakage resistance of a high-power transistor, a low resistance reading indicates a bad transistor. True or False?

38. **Why is it important to exercise great care in unsoldering a transistor from a printed circuit board?**

39. **What is the most reliable test of a suspected transistor?**

3. Locate the faulty stage.
4. Locate the faulty circuit.
5. Find the defect.

The two general types of testing methods are the dynamic tests and the static tests. Dynamic tests show how the signal is affected by the circuits under test. The commonly used tests of this type are signal injection and signal tracing. Static tests are tests of circuit condition when there is no signal applied. These tests include voltage testing, current measurement, resistance measurement and continuity testing.

Other commonly used tests include part substitution and opening connections. The frequently employed procedure known as bridging is one form of part substitution.

The nature of the symptom, information obtained in the initial checks, and usually some form of dynamic testing all help to locate the faulty section or stage. After this, usually one or more static tests are needed to locate the faulty circuit. These often indicate the faulty component. The part substitution type of check is often performed to determine whether the suspected component actually is defective. Normally, transistors and integrated circuits are the last types of components to be suspected. Transients and excessive voltage may damage or destroy transistors and integrated circuits.

IMPORTANT DEFINITIONS

CONTINUITY TESTING—A form of resistance test in which the circuit is tested for a complete dc current path.

DYNAMIC TEST—A test that consists of observing how a circuit affects a signal.

SIGNAL INJECTION—A dynamic test in which a signal is applied at various points throughout a defective unit, and the resultant output of the unit is observed. Also called SIGNAL SUBSTITUTION.

SIGNAL SUBSTITUTION—See SIGNAL INJECTION.

SIGNAL TRACING—A dynamic test in which the unit receives its normal input signal, and the presence, absence or distortion of this signal is observed at various points in the unit.

STATIC TEST—A test of circuit conditions with no signal applied.

PRACTICE EXERCISE SOLUTIONS

1. (a) Determine the symptom.
   (b) Make initial checks.
   (c) Locate the faulty stage.
   (d) Locate the faulty circuit.
   (e) Find the defect.

2. Signal injection and signal tracing.

3. Voltage, current and resistance measurements.

4. The trouble must be in the a-f amplifier stage.

5. A modulated signal at the i-f frequency of the receiver.

6. The trouble is most likely in the r-f amplifier stage.

7. True

8. In signal tracing the normal operating signal of the unit under test serves as the signal source, and an output indicator is used to test for the signal at various points in the unit. In signal injection a test signal is injected into the unit and the normal output device of the unit indicates whether or not the test signal is being handled properly.

9. False—The trouble must precede TP, which would place it in the r-f or i-f circuits.

10. True

11. This is done to offset the capacitance added to the circuit by the signal tracer, which tends to detune the circuit.

12. False—The oscillator signal is a constant amplitude, unmodulated signal.

13. True

14. False—The signal at this point is demodulated by the receiver.

15. A circuit defect may cause the voltage to be greater than that listed in the service literature. The recommended method is to start with a higher range, and then switch down to a lower range when you are sure the voltage does not exceed this lower range.

16. True

17. Measure the voltage across a resistor that carries the current, and then apply Ohm's Law to calculate the current.

PRACTICE EXERCISE SOLUTIONS (Continued)

18. Current tests are generally employed after dynamic tests have isolated the defective stage, and then only if voltage tests have not shown where the trouble is located.

19. (b) off.

20. One end of a component is disconnected to eliminate parallel current paths that would affect the resistance reading.

21. The low resistance does not necessarily indicate a defect because C_2 is in parallel with the T_1 primary, which will normally have a low resistance. For an accurate measurement, disconnect one end of C_2 and recheck the resistance between its leads. If the resistance is still low, C_2 is defective.

22. Continuity testing is used to check for a continuous dc current path.

23. There is a break in the connection between the C_1R_1 junction and the emitter of Q_1.

24. (b) an open in C_1.—If C_1 were shorted it would short out the "bridged" capacitor and not restore normal operation.

25. (a) emitter circuit.

26. (c) emitter.

27. The base is more positive (or less negative) than the emitter, and the collector is the most positive (or least negative) of the three elements.

28. This shows that the components within the dashed line are parts of a packaged circuit (PC_1). Combinations of resistors and capacitors are often made in this manner for printed circuit construction.

29. These squares locate key test points in the circuit.

30. Shining the light on one side of the board and viewing the board from the opposite side will give you an outline of the printed circuit and help you to locate various component connections.

31. False—Because they usually fail completely or change characteristics radically, integrated circuits are often easier to troubleshoot than discrete circuits.

32. Signals can be applied and outputs measured at various points, such as the numbered points in Figures 26 through 28. These are the external terminals of the circuit, which are often accessible through a mounting socket.

PRACTICE EXERCISE SOLUTIONS (Continued)

33. (a) in-circuit test is desirable.

34. True

35. The internal voltage source of the ohmmeter may produce enough current to damage the transistor.

36. Connect the test prods to the base and collector terminals of the transistor and note the resistance reading. Reverse the prods and again note the reading. For a normal junction, one reading should be about 5 to 10 times greater than the other.

37. False—A bad power transistor usually gives a zero resistance reading when shorted.

38. Care must be taken not to overheat the solder area to a point where it will damage the transistor or the circuit board.

39. The most reliable test is substitution with a unit known to be good.

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ONE OF THE
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7510A
EXAMINATION CHECK SHEET

7510A

1. B - IN THE BASIC TROUBLESHOOTING PROCEDURE, AFTER YOU HAVE FOUND THE FAULTY CIRCUIT, THE NEXT STEP IS TO -- FIND THE DEFECT.
Once you have found the defective stage you can employ voltage and resistance measurements to locate the defective component.

2. B - A TEST THAT PERMITS YOU TO SEE HOW THE SIGNAL IS AFFECTED BY THE CIRCUITS OF THE FAULTY UNIT IS CALLED A -- DYNAMIC TEST.
Dynamic tests involve signal tracing or signal injection to locate the defective stage.

3. B - WHICH OF THE FOLLOWING IS A STATIC TEST? -- VOLTAGE TESTING.
Voltage measurement is generally classed as a static test because the measurements are often made under no-signal conditions.

4. D - IN ONE TEST METHOD, YOU INTRODUCE THE SIGNAL FROM A GENERATOR INTO THE FAULTY UNIT AND OBSERVE THE RESULTING OUTPUT. THIS METHOD IS KNOWN AS -- SIGNAL INJECTION.
Signal injection employs a test signal from a suitable generator, whereas signal tracing employs the signal normally found in the unit.

5. C - EMPLOYING THE RECEIVER VOLUME CONTROL AS THE INITIAL TEST POINT -- DIVIDES THE RECEIVER INTO TWO SECTIONS.
The volume control divides the receiver into two sections, audio and i-f/r-f.

6. B - WHEN A SIGNAL TRACER INDICATES A NORMAL SIGNAL AT THE OUTPUT OF THE FIRST AUDIO STAGE IN A RADIO RECEIVER, YET THERE IS NO OUTPUT FROM THE SPEAKER, IT IS PROBABLE THAT THE TROUBLE IS IN THE -- OUTPUT STAGE OR SPEAKER.
When employing signal tracing, the trouble follows the last stage where a normal output is obtained.

7. C - WHEN MAKING VOLTAGE TESTS, YOU CAN CONSIDER A MEASURED VOLTAGE TO BE NORMAL -- IF IT IS WITHIN ±20% OF THE LISTED VALUE.
Unless otherwise indicated, voltage measurements are all right if within ±20% of the indicated values. In critical circuits the tolerance may not be as great.

8. B - IF THE SECONDARY WINDING OF T_1 IN FIGURE 19 OPENS -- THE EMITTER VOLTAGE WILL INCREASE TO NEARLY THE SUPPLY VOLTAGE.
With the secondary of T_1 open, base current is zero and only a small cutoff collector current exists. As a result, the voltage drop across the emitter resistor R_3 is reduced, increasing the emitter voltage to nearly 8.5 volts.

9. B - THE TRANSISTOR ELEMENT VOLTAGE THAT IS AFFECTED BY ALMOST EVERY CIRCUIT FAULT OR DEFECT INSIDE THE TRANSISTOR IS THE -- EMITTER VOLTAGE.
Most circuit defects alter either the base current, collector current or both. Because these currents combine to form the emitter current, it is always affected.

10. B - IF Q_1 IN FIGURE 20 DEVELOPS A BASE-TO-COLLECTOR SHORT -- THE BASE VOLTAGE WILL DROP TO NEAR ZERO.
A base-to-collector short will drop the base voltage to near zero as the collector is grounded through the primary winding of T_2.

QUESTIONS

IMPORTANT—These instructions **MUST** be accurately followed to avoid loss, or errors in grading.

Indicate your answer on this sheet by filling in the box for the most correct answer to each question, as illustrated in the example below.

When all questions have been answered, place the answer card in the proper position to line up the boxes on the card with the boxes on the sheet.

Next, copy the complete lesson code into the space provided on the card, and fill in the answer boxes to correspond with those previously filled in on this sheet.

Before mailing, be certain your correct student number, name and address appear on the card.

LESSON CODE
7510A

Example: An animal that is protected by a shell is the
A ☐
B ■
C ☐
D ☐
(A) dog. (B) turtle. (C) elephant. (D) cat.

1. A ☐ B ☒ C ☐ D ☐
In the basic troubleshooting procedure, after you have found the faulty circuit, the next step is to
(A) locate the faulty stage. (B) find the defect. (C) determine the symptom. (D) perform the initial checks.

2. A ☐ B ☒ C ☐ D ☐
A test that permits you to see how the signal is affected by the circuits of the faulty unit is called a
(A) resistance test. (B) dynamic test. (C) continuity test. (D) static test.

3. A ☐ B ☒ C ☐ D ☐
Which of the following is a static test?
(A) Waveform observation. (B) Voltage testing. (C) Signal tracing. (D) Signal injection.

4. A ☐ B ☐ C ☐ D ☒
In one test method, you introduce the signal from a generator into the faulty unit and observe the resulting output. This method is known as
(A) signal tracing. (B) static testing. (C) voltage analysis. (D) signal injection.

5. A ☐ B ☐ C ☒ D ☐
Employing the receiver volume control as the initial test point
(A) makes it unnecessary to check the r-f and i-f section. (B) is not recommended. (C) divides the receiver into two sections. (D) usually eliminates the need for any further testing.

6. A ☐ B ☒ C ☐ D ☐
When a signal tracer indicates a normal signal at the output of the first audio stage in a radio receiver, yet there is no output from the speaker, it is probable that the trouble is in the
(A) detector. (B) output stage or speaker. (C) antenna or r-f amplifier. (D) i-f circuits.

7. A ☐ B ☐ C ☒ D ☐
When making voltage tests, you can consider a measured voltage to be normal
(A) only if it is exactly equal to the value listed in the service manual. (B) if it is equal to or greater than the listed value, but not less than this value. (C) if it is within ±20% of the listed value. (D) if it is less but not greater than the listed value.

8. A ☐ B ☒ C ☐ D ☐
If the secondary winding of T_1 in Figure 19 opens,
(A) the collector voltage will increase. (B) the emitter voltage will increase to nearly the supply voltage. (C) the base voltage will drop to zero. (D) the emitter voltage will drop to zero.

9. A ☐ B ☒ C ☐ D ☐
The transistor element voltage that is affected by almost every circuit fault or defect inside the transistor is the
(A) supply voltage. (B) emitter voltage. (C) heater voltage. (D) base voltage.

10. A ☐ B ☒ C ☐ D ☐
If Q_1 in Figure 20 develops a base-to-collector short,
(A) the collector voltage will increase to −7.28 volts. (B) the base voltage will drop to near zero. (C) the emitter voltage will increase to −8.5 volts. (D) the emitter voltage will remain unchanged.

BROADCAST RADIO SERVICING

7515

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This unit includes all the test units normally required for servicing both AM and FM broadcast receivers. Included are an r-f generator, audio generator, power supply, in-circuit transistor tester and a multi-purpose meter.
Courtesy B & K Division of Dynascan Corp.

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Man's flight through life is
sustained by the power of his knowledge.
—Selected

BROADCAST RADIO SERVICING

In servicing any type of electronic equipment, you must quickly locate the defect through the application of a logical sequence of tests and measurements. There should be good logical reasons for each step, and each should move you closer to localizing the problem.

At many points in this planned approach you will make decisions as where to proceed next. These choices should always be based on the results of the tests already completed. Each step should either establish clearly that some section of the equipment is not at fault or point toward where the trouble lies.

In this lesson we will present a general plan of attack which can be applied to any radio servicing job. This plan may be varied when you deal with different types of equipment, but the method of analysis remains essentially the same.

To acquaint you with this method of troubleshooting, we will apply it to a common type of vacuum tube radio as found in many clock radios and other table models, and then to a transistorized portable radio. This lesson describes the general method of servicing, and then provides specific pointers on AM broadcast receiver troubles and how to locate faults in such receivers.

THE STEP-BY-STEP PLAN

The first step in troubleshooting is to establish the nature of the trouble. The customer report of the difficulty is your first clue and may sometimes contain information which alters your approach considerably. For instance, if the customer says a radio began to smoke and then blew the house fuse, you cannot safely plug in the radio before you locate the reason for the excess current.

In such a situation, you would begin your measurements with ohmmeter tests to locate the short. You would also want to make a careful visual inspection to find the part or parts which overheated and caused the smoke. You may find a charred resistor that will lead you to the trouble area in a hurry.

Most customers are vague in their descriptions of trouble because they have had no electronic training. For this reason, don't rely completely on what the customer says. Unless his report indicates that further damage may occur if you apply power to the unit, turn it on and observe its operation.

After having heard or read the customer's report and satisfied yourself that it correctly describes the trouble, you can draw some conclusions as to possible causes.

In situations where a receiver is completely dead, you may find by visual inspection that the filaments in a vacuum tube circuit are not lighting, or that the battery is dead in a transistor circuit.

At each step in your analysis, your next step depends on what you have learned up to that point. There is no point in measuring plate voltages in a radio if you already know the filaments are not lit—the logical approach would be to concentrate on finding out why the filaments are not lit. Perhaps it is simply an open filament in an ac-dc receiver, in which all filaments are connected in series. Tubes can be checked quickly by substitution or with a tube tester. Perhaps it is a bad switch, and no power is reaching the circuit. You can check this possibility with voltage or continuity tests.

Assume that a radio is producing no sound. You must establish whether or not power is reaching the radio, whether or not r-f and i-f sections are functioning, and whether or not the audio section of the radio is working. Each of these questions narrows the area which needs further investigation. By following such a plan, you can almost always eliminate large sections of the circuit with a few simple tests.

Once the trouble is localized, you can proceed to more thorough tests in the affected area. Voltage and resistance tests may be required at this point. But notice that you now know where to look. You will be measuring only in sections of the receiver where the trouble is likely to be located.

When your measurements reveal a defective component, replace it and turn the receiver on again to make sure the repair job is complete. There may be more than one problem.

Once you are satisfied that the radio is in working order, reassemble it in the cabinet and get it ready for return to the owner.

This preliminary look at the typical service routine has been generalized. We will go through the same general procedure again and again as it applies to many different types of equipment. What we hope to illustrate here is the value of following a logical sequence of tests. Each test should either bring you closer to the solution or rule out many steps which are not required in a given case.

SERVICING AN AC-DC VACUUM TUBE RADIO

Figure 1 is a schematic of a transformerless ac-dc receiver. This five-tube AM receiver circuit is found with minor variations in many clock radios and small table radios. The use of a line-operated power supply lowers the cost and provides a savings in weight and size. The tubes are chosen so that their filaments may be connected in series with the filament voltages adding up to the line voltage.

Normal Circuit Operation

Let's review the basic circuit to make sure you understand its operation. This is a standard superheterodyne circuit in which the incoming signal is mixed with a signal from the local oscillator to produce the i-f signal. The i-f signal is amplified and then detected to recover the audio information. The audio signal is amplified and applied to a speaker.

When the receiver is operating normally, the incoming signal is picked up by the antenna, mixed with the local oscillator signal in the 12BE6 converter stage V_1, and amplified. The output from this stage is always at the intermediate frequency, in this example 455 kHz. The i-f signal is coupled through i-f transformer T_1 to i-f amplifier V_2. The second i-f transformer, T_2, couples the output signal from V_2 to the diode detector section of V_3.

The audio signal appears across the volume control, R_4, and is coupled by capacitor C_4 to the grid of the triode section of V_3. This section of the tube acts as an audio voltage amplifier and provides the relatively large voltage swing required at the grid of power amplifier V_4. The output transformer, T_3, in the plate circuit of the V_4 stage develops the signal for the permanent magnet speaker which produces the sound output.

Automatic volume control (AVC) for the receiver is obtained from the detected signal appearing across R_4 and C_8. This negative control voltage is applied to the grids of V_1 and V_2, making the gains of both these stages dependent on the strength of the incoming signal.

The receiver is tuned by the two-gang capacitor, C_1. Section C_{1A} of this capacitor tunes the loopstick antenna to the incoming station. The other

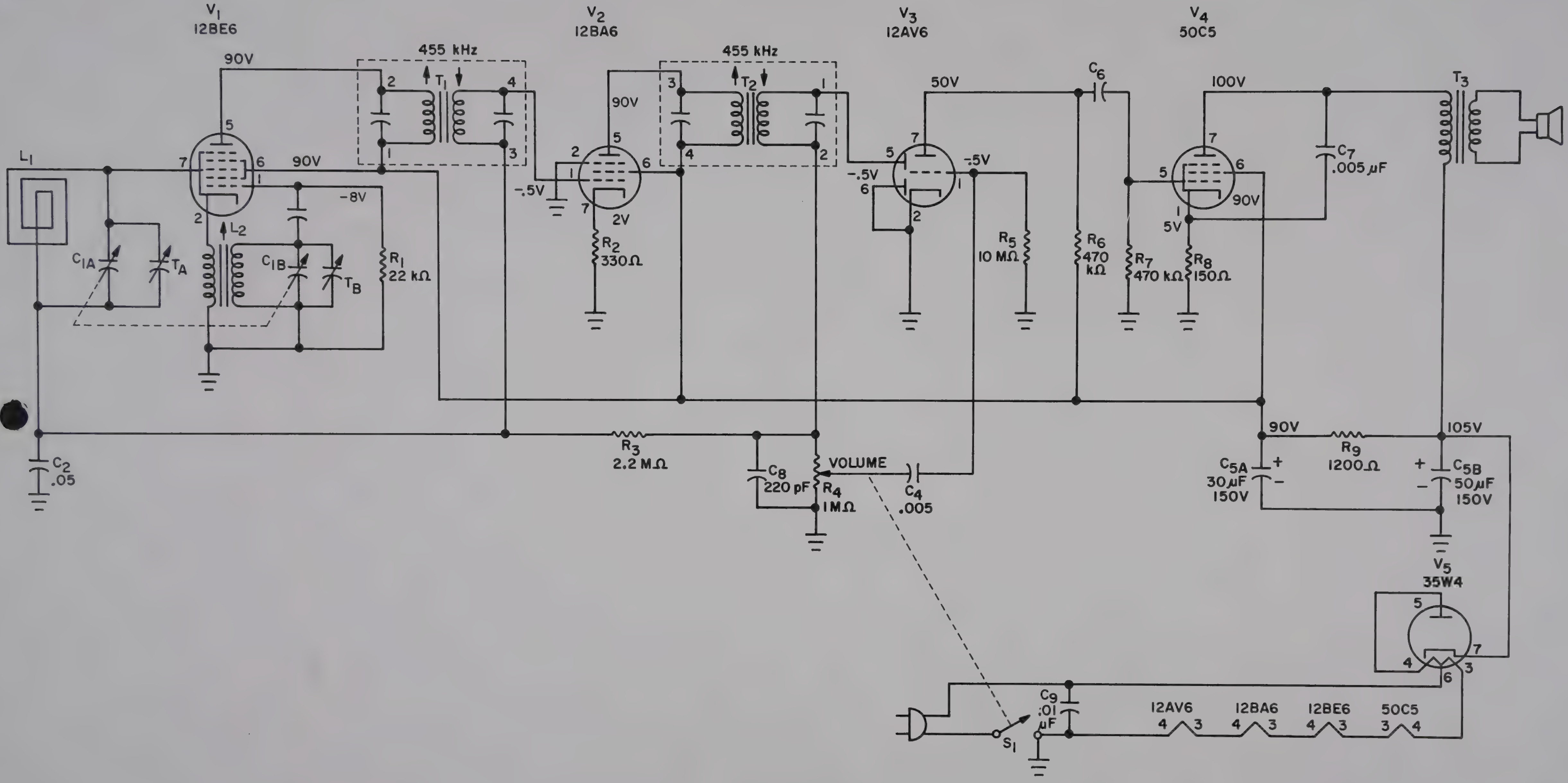

V1
12BE6
V2
12BA6
V3
12AV6
V4
50C5
455 kHz
T1
455 kHz
T2
90V
90V
90V
50V
100V
-8V
-.5V
-.5V
-.5V
-.5V
2V
5V
90V
C6
T3
L1
L2
C1A
TA
C1B
TB
R1
22 kΩ
R2
330Ω
R5
10 MΩ
R6
470 kΩ
R7
470 kΩ
R8
150Ω
C7
.005 μF
C2
.05
R3
2.2 MΩ
C8
220 pF
VOLUME
R4
1MΩ
C4
.005
90V
R9
1200Ω
105V
C5A
30μF
150V
C5B
50μF
150V
V5
35W4
C9
.01 μF
S1
12AV6
12BA6
12BE6
50C5

Figure 1

section (C_{1B}) adjusts the frequency of the local oscillator so that it is 455 kHz above the incoming signal. Trimmer capacitors T_A and T_B across C_{1A} and C_{1B} provide fine adjustments for alignment. When the incoming and oscillator signals heterodyne in V_1, they produce a 455-kHz difference signal. The original r-f signal and the oscillator signal are well above the frequency to which the V_2 stage is tuned so that they do not appear in the T_1 output.

The half-wave rectifier, V_5, provides the dc power required by the tubes. Components C_{5A}, C_{5B} and R_9 provide power supply filtering.

Preliminary Troubleshooting Steps

Let's assume that this radio is brought into the shop for repair. The customer reports no sound output. Assuming that nothing in his report indicates overheating, and that you can see no obvious signs of damage, it is probably safe to plug the line cord into an isolation transformer and turn on the radio.

The first thing to establish is whether or not the filaments light. If they do not, there may be an open filament somewhere in the series string. With an open filament, the entire receiver will not light. This is most easily found by tube substitution. Change one tube at a time until you locate the open. If replacements are not on hand, you can test the tubes on a tube tester, or use an ohmmeter to locate the open filament. Resistance between the two filament pins (usually pins 3 and 4 in 7-pin miniature tubes and pins 4 and 5 in 9-pin miniature tubes) should be very low. Next, inspect the line cord for signs of breaks in the conductor.

If the tube filaments and line cord are all in good order, yet the tubes do not light, the chassis must be removed from the cabinet for further tests. This usually involves removing any knobs or dials that attach to the controls, and removing the screws that hold the chassis in the cabinet. In some situations, the speaker does not come out of the cabinet with the chassis, and must be disconnected. Some receivers also have a cabinet-mounted antenna which must be disconnected before removing the chassis. Remember, for safety, you must plug the ac-dc radio into an isolation transformer before proceeding further.

Once you have removed the chassis, visually inspect the components. You may find evidence of burned or heated components which will lead you directly to the trouble area. If there is no visible damage, measure the ac line voltage across C_9, the line filter capacitor. With the switch turned on, there should be line voltage at this point. If not, the fault may prove to be in the switch or the line cord.

Assume that the filaments light in the receiver shown in Figure 1, yet there is no sound from the speaker. Because tube failure is by far the most common source of trouble in all vacuum tube equipment, check the tubes as one of your preliminary tests. Direct substitution of new tubes is preferred to a test on a tube tester. The tubes in this circuit are all common types and should be part of the tube stock in the service shop. If tube replacement restores normal operation, and a test run shows no further difficulties, the repair is complete.

When a rectifier tube is substituted before the power supply has been checked for shorts, it is a good idea to watch it closely when power is applied. If the rectifier plates glow, turn off the receiver and check the power supply circuit before proceeding further. If there is a direct short on the power supply, such as a shorted filter capacitor, the new rectifier tube may be damaged because of excess current drawn by the shorted part.

Dividing the Circuit at the Volume Control

If tube replacement does not correct the trouble, you must check further. There is a quick test which can greatly reduce the area of the search and shorten the troubleshooting time. This test consists of injecting an audio signal at the volume control and listening to the resulting sound from the speaker. All elements between the volume control and the speaker handle audio frequencies, while those preceding this point handle radio frequencies. The only unit shared by the two halves of the receiver is the power supply. If the trouble is in the power supply, neither half will work properly.

If you touch the ungrounded end of the volume control with a probe such as a screwdriver held in your hand, 60 Hz ac will enter the circuit at this point. If the volume control is set fully open and the audio section is operating, this will produce a loud hum in the speaker. If the trouble is between the volume control and the speaker, nothing will be heard.

An alternate method is to use an audio generator and feed the signal into the volume control. If the audio section is working, you will hear the tone from the speaker.

To illustrate this simple test, let's consider three of the many possible troubles that might result in no sound from the receiver of Figure 1. First we will consider an open speaker voice coil, then a shorted output filter capacitor (C_{5A}) in the power supply, and finally an open secondary in T_2, the second i-f transformer.

In each of these examples, the symptom would be a "dead" receiver. Assume that a visual inspection shows that the tubes are lit; you know the filament string is intact and power is reaching the receiver. Tube replacement does not clear up the trouble, so you are forced to remove the chassis for further tests.

In the first situation, we assumed a defective speaker. A receiver with this defect certainly won't produce any sound when you touch the volume control. What have you proved with this quick audio test? You now KNOW that the trouble is either in the audio or power supply sections of the receiver.

In the second situation (C_{5A} shorted) you would again hear nothing when you touch the volume control. This time the cause is lack of B+ voltage on the plates of the tubes, but again from the test results you will conclude that the trouble is in either the audio or power supply sections of the receiver.

In the third situation (T_2 open), the trouble lies ahead of the volume control. If you touch the volume control or apply an audio signal to the ungrounded end of the volume control, the signal will pass through the audio section in the normal way. The speaker output means that the audio section and power supply are in operating condition, and you can confine your search to the circuits preceding the volume control.

This audio generator is useful in checking the audio section of radio receivers.

Courtesy Heath Company

In each of these situations, a relatively simple test narrows down the search to about half the receiver. Additional tests will localize the trouble to a specific section and then to a specific component.

Isolating the Defective Section

Once you have narrowed down the trouble by this process of inserting a signal at the volume control, you can move to the defective area. For example, let's assume the trouble is a defective speaker voice coil. Your initial tests tell you the trouble is in either the power supply or the audio section. Your next step would be to measure the power supply voltages.

In Figure 1, the voltages are marked 105 volts at the input to the power supply filter and 90 volts at the output of the filter. These are typical values for receivers of this type. With a defective speaker, these voltages would measure correctly, so you can rule out the power supply as the trouble source. The open speaker voice coil would have very little effect on current through the power amplifier, so all voltages measure near normal.

You are now certain the trouble is in the audio section. You again narrow down the search area by feeding an audio signal or touching your probe to the grid of the power amplifier, V_4. Normally, you should hear an output when you touch this point. However, in this instance no sound comes through.

Your next step would be to measure the voltages at the various pins of V_4. All would be near normal in this example.

The fact that normal cathode voltage is present indicates that current is through V_4. Because no sound is produced, all that remains is to check the output transformer and the speaker.

At this point the quickest test is to turn off the radio and check the transformer and speaker with an ohmmeter. You already know the primary is not open because the voltage at the plate of V_4 is normal. This means that plate current must be passing through the transformer primary.

Your next step is to check the secondary of T_3, which should provide a low ohmmeter reading if it is not open. However, to measure either the secondary or the speaker voice coil independently, you must unsolder one of the speaker leads. This would reveal the trouble because you would have a normal low resistance path from one side of the transformer secondary to the other, but when you check the voice coil you would get an open reading.

Connecting another speaker across the secondary of the transformer should restore normal operation.

If you review the steps taken in this analysis, you will see that each step moved you toward the solution of the problem. You first concluded that the trouble was in the audio or power supply sections. Voltage measurements eliminated the power supply. You injected a signal at the grid of the power amplifier and so proved the trouble was between this point and the speaker. Voltage tests showed you that the tube was conducting, so you were led to investigate the speaker, which proved to be the defective part.

Let's now consider the second test example. The receiver has a short in filter capacitor C_{5A}. It is possible that this trouble might also have caused R_9 to open or change resistance because of the excessive current. It might also have caused damage to the rectifier tube. We will assume that neither of these things happened, and nothing else is wrong but the shorted output filter capacitor, C_{5A}.

Again, your first test is the signal injection test at the volume control, which produces no sound from the speaker. This means you should again move to an investigation of the power supply and the audio output stage.

The next step is to measure the voltages in the power supply. In this example, the voltage tests would lead you directly to the trouble. The voltage at C_{5A} is zero volts or at least very much below normal. Your next step is to disconnect the leads from this capacitor and take an ohmmeter reading which would end your search.

Notice that here you could not be sure where the short was until the capacitor was disconnected. A short anywhere on the 90-volt B+ line would cause a zero reading across the capacitor.

Electrolytic capacitors used in power supply filter circuits are often multi-section capacitors. For example, C_{5A} and C_{5B} in this receiver are probably in a single "can" with a common ground terminal. If one section is defective, replace the complete unit. If R_9 shows any evidence of overheating, or if its value has changed as a result of the heavy current drawn by the shorted capacitor, you should also replace it.

Now let's consider the example of an open secondary in T_2, the second i-f transformer. The signal injection test at the ungrounded terminal of the volume control results in an output from the speaker. Thus, you may conclude that both the audio section and the power supply are operating satisfactorily. For that reason, none of the tests we have described in connection with the other examples would be necessary.

This time you move directly from the volume control test to V_2 and work back toward the antenna. A good approach is to inject a modulated 455-kHz i-f signal at the grid of V_2 and check for an audio tone in the speaker. If you hear the modulation tone when the signal is injected at this point, you can assume that the V_2 stage is functioning, and move back to the V_1 stage for further tests. However, with the open T_2 secondary, there will be no output when the signal is injected at the grid of V_2. The trouble must be between the grid of V_2 and the volume control.

We now have another good point to check—the avc voltage. This voltage should vary noticeably as the output of the signal generator is increased or decreased. With the open i-f transformer in this receiver, there will be no avc voltage variation because no signal is reaching the detector.

The next step is to measure the voltages in the V_2 stage. With an open in the T_2 secondary, the plate, screen grid and cathode voltages of V_2 will be normal. This tells you that the V_2 stage, including the primary of T_2, is in working order. Suspicion then points to the secondary of T_2. An ohmmeter reading across this winding will pinpoint the trouble.

Replacement of the i-f transformer will restore operation, but the transformer may require alignment before normal performance can be achieved. Whenever tunable parts are changed during servicing, alignment will be required.

From these three examples of typical troubles in broadcast receivers, you should be able to see the value of a logical plan of attack. Each test is intended to limit the area that requires further investigation. This step-by-step isolation of the defect is the secret of effective troubleshooting.

Some troubles which can occur in a radio are more difficult to locate than those used as examples in this lesson. There are, for instance, examples of intermittent operation which seem to disappear whenever you attempt to make a measurement. These can be very difficult to isolate. There are also examples of multiple troubles where making the logical repair does not seem to accomplish anything.

Most troubles, however, yield quickly and easily to the logical approach presented here. When we apply these techniques to transistor circuits, there will be some differences in the measurements taken, but the logic of proceeding to isolate the defective stage remains essentially the same.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

THE STEP-BY-STEP PLAN

SERVICING AN AC-DC VACUUM TUBE RADIO

NORMAL CIRCUIT OPERATION

PRELIMINARY TROUBLESHOOTING STEPS

DIVIDING THE CIRCUIT AT THE VOLUME CONTROL

ISOLATING THE DEFECTIVE SECTION

1. In a logical approach to radio troubleshooting, the result of one test often determines what other tests should follow. True or False?

2. A customer reports that his radio suddenly quit in the middle of a program. He left it turned on for some time, but heard nothing at all. Is it safe to apply power to this radio?

3. A customer states that smoke comes from his clock radio whenever it it turned on. Can power be safely applied to this radio before performing tests to locate the cause of the smoke?

4. In an ac-dc vacuum tube radio in which the filaments are not lit, which of the following tests would you perform first? (a) Measure the B+ voltage. (b) Test the tubes. (c) Perform an i-f alignment.

5. In the circuit of Figure 1, to what frequency is T_2 tuned when the receiver is receiving a station at 720 kHz on the dial?

6. What is the function of C_{5A} and C_{5B} in the receiver of Figure 1?

7. What two functions are performed by V_3 in the receiver of Figure 1?

8. In the radio of Figure 1, are the tube filaments connected in series or parallel?

9. In the receiver of Figure 1, what would be the result of an open heater in V_3?

10. What precaution must be observed when checking for a defective rectifier tube by direct substitution?

11. Assume that the local oscillator is defective in the receiver of Figure 1. What should you hear if you touch the ungrounded terminal of the volume control with the tip of a screwdriver?

12. In Figure 1, why does the presence of cathode voltage on V_4 indicate that the tube is conducting?

13. If the trouble in the receiver of Figure 1 had been an open primary winding in the output transformer, which of the voltage measurements on V_4 would have led you to the trouble?

14. In Figure 1, assume that the short indicated at C_{5A} is not the result of the filter capacitor being internally shorted. What would happen if the capacitor leads at this point were disconnected?

15. Assuming that the condition of Practice Exercise 14 exists, what other points would you check to locate the short?

16. At what points in the receiver of Figure 1 can the avc voltage be measured?

17. A receiver like that of Figure 1 has normal B+ voltage, but no audio output when a signal is injected at the volume control. Which of the following might be the cause of the trouble? (a) Weak 12BE6. (b) C_4 open. (c) C_{5B} shorted. (d) T_1 open.

18. Assume that the receiver of Figure 1 has normal B+ voltage and produces a loud hum when you touch the ungrounded terminal of the volume control, but no stations can be tuned in. Which of the following might be the cause of the trouble? (a) V_4 not operating. (b) C_4 open. (c) C_{5B} shorted. (d) T_1 open.

SERVICING A TRANSISTOR PORTABLE RADIO

We will now consider the application of logical troubleshooting methods to transistorized equipment. Transistor AM radios, both the small portable variety and the table and console types for the home, are probably the most popular receivers on the market.

When a transistor portable radio requires service, there is often some question as to whether or not the repair is worth the cost. A serviceman cannot afford to spend much time troubleshooting a unit which can be replaced for a few dollars. In such instances, if the defect cannot be located and corrected quickly, it may be cheaper to discard the unit and buy a new one. There are, however, many transistor radios costing enough to justify extensive repair.

We have omitted the very simple four and five transistor portables from our study. Often they can be repaired using exactly the same techniques we will discuss, but usually the repair is not warranted.

A circuit of a transistorized portable AM receiver is shown in Figure 2. The circuit shown uses eight PNP transistors and a diode detector. It has a 3-volt supply made up of two 1.5-volt cells. This receiver is chosen to illustrate the servicing techniques required for all such receivers.

We will first examine the normal operation of the receiver before considering troubles that may require service. Like the vacuum tube receiver of Figure 1, the transistorized receiver of Figure 2 is a superheterodyne circuit. It includes a converter stage which develops an i-f signal by combining the incoming r-f signal with an oscillator signal. The i-f signal is amplified by two i-f amplifier stages, and is then applied to a diode detector. The resultant audio signal is amplified by the audio amplifier section, which includes a push-pull output stage.

The incoming signal is picked up by the built-in ferrite bar antenna and fed to the base of converter Q_1. The antenna circuit is tuned by C_{12A}. Q_1 also serves as the local oscillator. The tuned circuit consisting of L_2 and C_{12B} determines the frequency of oscillation. The smaller winding of this coil is connected in the collector circuit and provides the necessary feedback.

The oscillator operates 455 kHz above the incoming r-f signal to produce the i-f signal. L_3 in the collector circuit of Q_1 is a tuned i-f transformer which couples the 455 kHz difference frequency, produced by heterodyning the oscillator and incoming r-f signals to the base of Q_2. Both Q_2 and Q_3 are i-f amplifiers. Each of the i-f stages has a small portion of its output signal returned out-of-phase to the input through a 3-pF capacitor to neutralize the stage and eliminate unwanted oscillation.

Q_4 is the diode detector. The audio portion of its output, developed across volume control R_{11}, is applied to the audio amplifier through C_7. Any r-f present at this point is bypassed by C_6. AVC voltage is also developed across the volume control and fed back to the base of Q_2 through R_5. C_3 provides the necessary filtering for the avc voltage.

The audio signal from the volume control goes to the base of Q_5, the first audio amplifier. Q_6 receives its input signal from the emitter of Q_5. The base signals of Q_5 and Q_6 are in phase with each other and R_{16} is common to the collector circuits of both of these transistors. The current amplification of both transistors controls the voltage swing across load resistance R_{16}.

The voltage across R_{16} is coupled to the base of Q_7, where it is amplified and then transformer coupled to the push-pull power amplifier (Q_8 and Q_9). An equal amount of audio input is delivered to the base of each of these output transistors by the center tapped transformer, L_6. These two signals are 180 degrees out-of-phase as are the collector signals appearing at opposite ends of L_7.

Output transformer L_7 couples the power output from the transistors to the speaker or to the phone jack when an earphone is used. A small amount of this signal is also coupled back to the input of Q_5 by feedback resistor R_{21}. This feedback signal is out-of-phase with the input signal from the volume control and serves to reduce any distortion occurring in the audio amplifiers.

Let's now consider the service problems which are commonly encountered in receivers of this type. If the radio comes into the shop with a complaint of no output, the first consideration is always the power supply. Battery life is limited, and the battery is always a good point to start your examination. Don't rely on a customer's comment that the battery is new.

Battery voltage can be measured at the terminals where the batteries connect to the circuit board, or from the collector to emitter of either output transistor, Q_8 or Q_9. Measuring voltage at this latter point, you also verify continuity in the primary of L_7. The voltage measurements should be made with the radio turned on, as a weak battery may read near normal voltage when no-load current is being drawn.

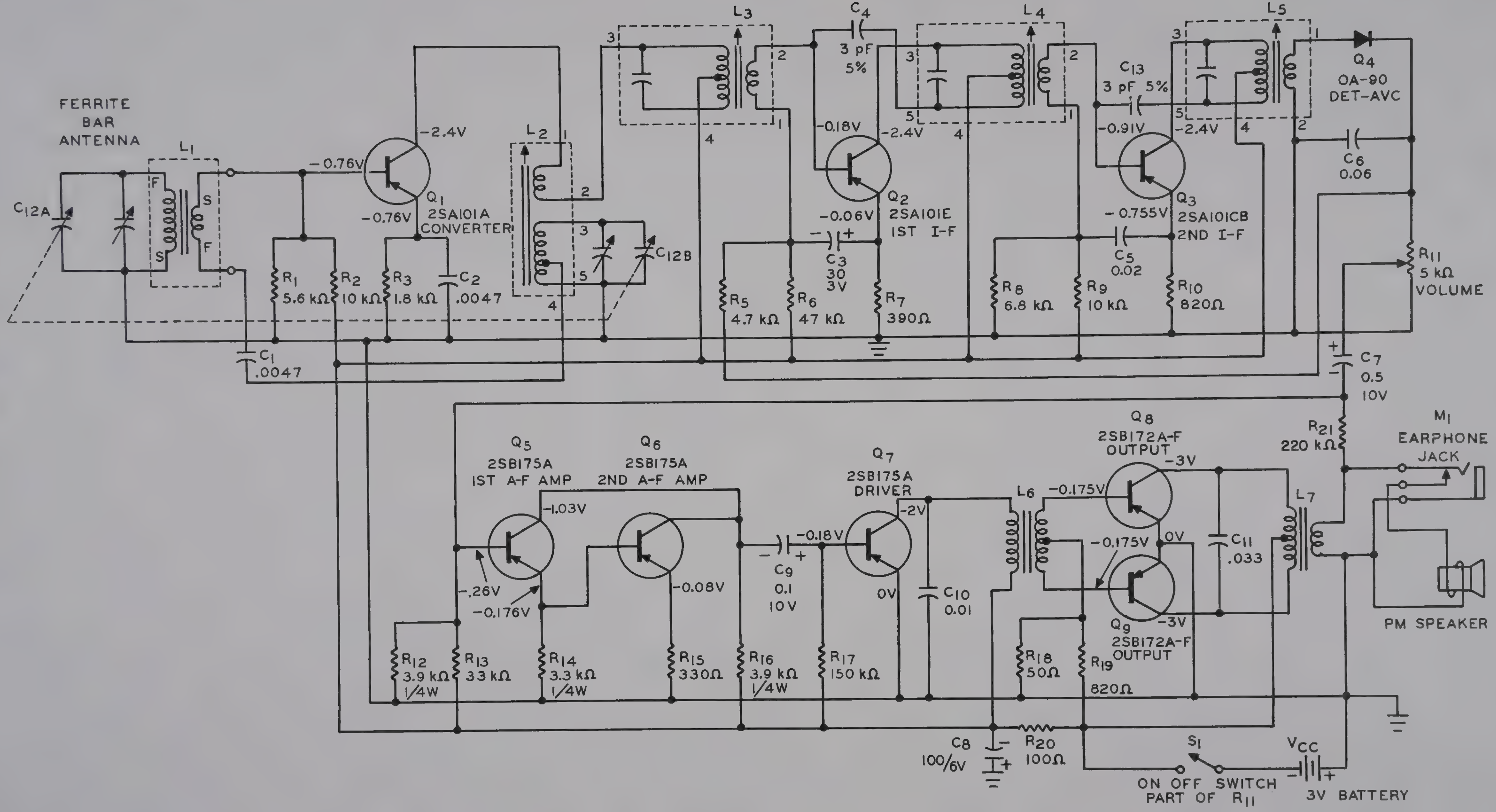

FERRITE BAR ANTENNA
C12A
L1
F
S
S
F
−0.76V
−2.4V
Q1
2SA101A CONVERTER
−0.76V
L2
1
2
3
5
4
C12B
R1 5.6 kΩ
R2 10 kΩ
R3 1.8 kΩ
C2 .0047
C1 .0047
L3
3
2
1
4
C4
3 pF 5%
−0.18V
−2.4V
Q2
2SA101E 1ST I-F
−0.06V
C3 30 3V
R5 4.7 kΩ
R6 47 kΩ
R7 390Ω
L4
3
2
5
1
4
C13
3 pF 5%
−0.91V
−2.4V
Q3
2SA101CB 2ND I-F
−0.755V
C5 0.02
R8 6.8 kΩ
R9 10 kΩ
R10 820Ω
L5
3
1
5
4
2
Q4
OA-90 DET-AVC
C6 0.06
R11 5 kΩ VOLUME
C7 0.5 10V
R21 220 kΩ
Q5
2SB175A
1ST A-F AMP
−1.03V
−.26V
−0.176V
Q6
2SB175A
2ND A-F AMP
−0.08V
Q7
2SB175A DRIVER
−2V
−0.18V
0V
C9 0.1 10V
C10 0.01
R12 3.9 kΩ 1/4W
R13 33 kΩ
R14 3.3 kΩ 1/4W
R15 330Ω
R16 3.9 kΩ 1/4W
R17 150 kΩ
L6
−0.175V
−0.175V
Q8
2SB172A-F OUTPUT
−3V
0V
C11 .033
Q9
2SB172A-F OUTPUT
−3V
L7
R18 50Ω
R19 820Ω
M1 EARPHONE JACK
PM SPEAKER
C8 100/6V
R20 100Ω
S1
ON OFF SWITCH PART OF R11
VCC
3V BATTERY

Figure 2

Checking the Audio Section

The same division at the volume control can be accomplished in this receiver as in the ac-dc vacuum tube receiver. The probe used in the tube radio will not produce as much hum in transistor radios because of the much lower impedance in the transistor circuits. You can, however, generate noise clicks when touching any of the base contacts in the audio section if this section of the radio is functioning properly.

A better test can be obtained by inserting a test signal from an audio generator. Keep the level of the input signal low and connect one lead to the common ground and the other lead to the ungrounded end of the volume control or the base of the audio stage to be checked. If the signal comes through from the volume control, yet the receiver does not produce any output when tuned to a radio station, the trouble is in the circuits which precede the volume control.

This in-circuit transistor tester permits the testing of transistors without removing them from the circuit.
Courtesy Hickok Electrical Instrument Co.

If the audio signal does not come through when applied to the volume control, move the signal source to the base of the next stage nearer the speaker. Keep moving stage by stage toward the speaker until you are able to hear the audio tone. The preceding stage, where you were unable to get the tone, is then the defective stage.

If no signal can be heard when you touch the volume control, yet the batteries are providing power, move your probe toward the speaker and touch the base of each transistor in turn until sound is produced. If no sound has been heard when you have done this to all audio stages, the trouble must be in the speaker, the output transformer or the earphone jack. An ohmmeter should provide you with the answer as to which of these is at fault.

A fairly common fault in transistor radios of this kind is an open earphone jack. This results in the radio being entirely dead because there is no connection to the speaker unless the spring contact on this jack is closing properly. Plugging in an earphone will check for this and may locate the trouble promptly.

Assume that you are able to isolate a defect to one of the audio stages. For example, let's assume that in the receiver of Figure 2, checks in the audio section show that no signal is getting through Q_7. That is, introducing an audio signal to the base of this transistor has no effect, while touching either base of the push-pull stage does produce sound.

Your next step is to measure the voltages in the Q_7 stage. Assume that in the process of your voltage tests you find that the base voltage is more negative than the value specified in the manufacturer's diagram. In fact, it is very near the collector voltage, which is also more negative than shown on the schematic. When you measure the voltage at the emitter you find it to be zero, which is normal for this point.

The combination of high collector voltage and high base voltage leads you to suspect that the transistor is open. If the transistor were conducting, the high base voltage would result in heavy collector current which, in turn, would lower the collector voltage caused by the increase in voltage drop across R_{20}.

To determine whether or not the base bias still controls the transistor, you can temporarily alter this bias by touching another resistor across R_{17}, the source of this bias voltage. The most satisfactory test is with a resistor of the same size as is used in the circuit. In this example, R_{17} is a 150-kΩ resistor. If you held another 150-kΩ resistor in parallel with this one, the collector voltage should change noticeably if the transistor is conducting. If the transistor is open, the additional resistor will have no effect.

You must also establish whether the open circuit is in the transistor or the circuit board. If the path from the collector to L_6 were open, the collector voltage would be zero. Likewise, if either end of R_{17} were disconnected, the base voltage would not be high. If the path from the emitter terminal to ground were broken at some point external to the transistor, the voltage measured at the emitter would be the same as that at the base and collector.

Let's examine the Q_7 stage a bit more closely and see what various abnormal voltage readings may reveal. Assume that you have decided this stage is defective, but you aren't sure what is wrong. If you measure no voltage on the collector of Q_7, you would suspect the primary of L_6 or the path between L_6 and the transistor, or between L_6 and the power supply. An ohmmeter would tell you which is defective.

If the voltage on the collector is high, but the voltage on the base is low, you suspect one of the leads from R_{17}. If the voltage at the emitter in this stage measures anything but zero, the lead to the common ground point must be open. If there were an emitter resistor, as in the Q_5 stage, the emitter voltage normally would not be zero. But if the emitter and collector voltages are both high, the emitter circuit may be open.

On printed circuit boards, open circuits caused by small breaks in the etched copper circuit are not unusual. They can best be found with the ohmmeter once a voltage measurement has indicated the possibility of their being present in a particular lead. To repair such a break once it is located, you can flow solder across the break or solder a wire across it. Do this with care to avoid shorting to adjacent conductors. Also, avoid overheating in such repairs or the foil strip may peel off the circuit board.

Assume that voltage measurements around Q_7 suggest a shorted rather than open transistor. A short from emitter to base will cut off any current through the transistor, and thus will cause the collector voltage to rise. The base voltage will decrease to the emitter voltage. Conversely, a short from collector to either emitter or base will cause the collector voltage to be far below its normal value.

In any situation involving a shorted transistor, there will be at least two transistor terminals with identical voltages. Usually, these are different enough from the normal to be obvious. In the Q_7 stage of Figure 2 an emitter-to-base short will cause both the emitter and base voltage to read zero and the collector voltage to read high, perhaps -2.8 volts.

Consider briefly the results of shorts and opens in the push-pull audio output transistors, Q_8 and Q_9. An open circuit in one of these transistors would not produce the no-sound condition we have assumed. If an open occurred, the remaining transistor would continue to conduct and you would get some form of output, although it might be badly distorted.

Conversely, open leads external to the transistors may cause both the transistors to be inoperative. If the lead from the center tap of L_7 to $-V_{CC}$ were open, neither transistor would have collector voltage. Similarly, both transistors connect to ground through a common lead to their emitters and would both be inoperative if this lead were open.

A short in either of the push-pull transistors will affect the other. A short from collector to base would raise the base voltage on both transistors while a short from emitter to base would lower both bases to very near ground potential.

Having checked out various possibilities in the audio section, we will quickly review the steps we have considered. The first step is to verify the condition of the battery. After the battery is eliminated as a source of trouble, seek out the defective stage by touching an audio signal source to the base of each transistor, beginning at the volume control and going toward the speaker. Also, check the earphone jack and the condition of the speaker voice coil. If the signal injection check points out the defective stage, proceed with voltage tests within that stage, followed by substitution or resistance tests of the suspected components.

One problem which often complicates the task of isolating the defective stage in transistor receivers is that a short or open at certain points may alter voltages on several stages. For example, assume that C_{10} in Figure 2 is shorted. This effectively connects the collector of Q_7 to ground. This will not only cause Q_7 to be inoperative, but will lower the voltages on all preceding stages because the voltage drop across R_{20} is increased considerably. In such situations, it becomes more difficult to determine which stage is the original source of the trouble and which stages are inoperative because of the changes in voltages.

There are one or two other possibilities to be considered as possible sources of trouble in the audio section. There are two coupling capacitors, either of which might cause a dead receiver. C_7 couples the signal from the volume control to the base of Q_5, and C_9 couples the output of Q_6 to the input of Q_7. If either of these capacitors were open, dc voltage readings would be normal but no sound would be produced. C_7 might be suspected if injecting audio at the volume control has no effect but touching the base of Q_5 produces a sound.

An open coupling capacitor in any audio stage results in an interruption of the signal path, but little or no change in dc measurements. Conversely, a shorted coupling capacitor will first change the base bias voltage on the following stage, resulting in increased current through the transistor and a decrease of collector voltage.

In addition to the coupling capacitors, there are three other capacitors in the audio section of the receiver of Figure 2 whose failure might cause problems. If C_{11} across the output transformer were shorted, no signal could be developed across the transformer. If this capacitor were open, there would be a change in the frequency response but the receiver would not be dead as we have been assuming this receiver to be.

If C_{10} were open, there would again be some change in frequency response, but the receiver would otherwise be operational. Shorting this capacitor would short the collector of Q_7 to ground and cause the receiver to be dead. The voltage at this collector would then be zero and there would be a considerable current through L_6 and R_{20}. All preceding stages would have lower-than-normal operating voltages.

If C_8 were shorted, the voltages on all transistors before the output stages would be zero. The receiver would, of course, be dead and the battery would probably also be ruined. R_{20} might show signs of overheating.

Checking the I-F Section

Assume that the receiver shows normal operation of the audio stages when you inject a signal at the volume control, but no stations can be received. From this you can assume that the trouble lies at some point before the volume control.

Some type of an r-f signal generator is the best means of checking for the location of a defective stage in this portion of the receiver. To avoid overloading the receiver, the generator should be loosely coupled to the stage being tested. Merely bringing the leads from the generator close to the receiver may be sufficient without any direct connection.

To begin the search, introduce a modulated 455-kHz signal at the base of Q_3. If both this stage and the detector are functioning, you should hear the modulating tone from the speaker. Connecting a vacuum tube voltmeter or transistorized meter between the R_5, R_6 and C_3 junction and ground will allow you to measure the avc voltage. In this receiver, this point has a negative voltage of about .18 volt with no input signal. When a signal is received, a dc voltage is developed across the volume control by the rectifying action of the diode detector. This opposes the no-signal voltage on the avc line, so that as the signal strength increases, your meter should indicate a smaller negative avc voltage. It should never go positive, but may reduce the forward bias on Q_2 to a very small value.

To establish which stage is not operating, measure the voltage across C_3, with no signal applied. Then, insert the modulated i-f signal at the base of Q_3 and note the change in the voltage level across C_3. Increase the output from your signal generator or increase the coupling between the generator and the base circuit and see if this voltage varies. In any normally operating circuit the voltage will vary. If there is no output from the speaker, and no change takes place in the avc voltage, the trouble is in Q_3 or its associated circuit or the detector Q_4.

To check Q_4, feed the modulated i-f signal directly to the diode at the point where it connects to L_5. If you get an audio tone from the speaker, you are sure that the detector is operating. Your next step is to measure the voltages in the Q_3 stage.

The same tests for open and shorted transistors can be made for Q_3 as were suggested for Q_7. Paralleling R_9 with a similar resistor should change the voltage at the emitter considerably. The effect on the emitter voltage will now be more noticeable than the change in collector voltage. This is because the resistance in the emitter circuit is greater than the dc resistance in the collector circuit. Because the current in both emitter and collector are substantially the same, the voltage change is greater across the emitter resistance.

An open in L_5 primary would cause the Q_3 stage to be inoperative. If the primary side of the coil were open above the center tap, there would be no collector voltage on Q_3. If it were open below the center tap, there would be no resonant circuit, but the collector voltage would still be present. If the secondary side of L_5 were open, no signal would reach the diode. You can check each of these possibilities with an ohmmeter.

The function of C_{13}, connected from the bottom of the L_5 primary to the base of Q_3, is to provide feedback and prevent the stage from oscillating. If this capacitor is open, and oscillation occurs in the stage, there will be a large avc voltage developed and the voltage at the junction of R_5, R_6 and C_3 may become positive even with no signal applied.

If Q_3 and the detector appear to be operating, apply the modulated 455-kHz signal to the base of Q_2. The operation of this stage is nearly identical to that of

The following Practice Exercise questions cover the subjects which you have just studied. They are:

SERVICING A TRANSISTOR PORTABLE RADIO

CHECKING THE AUDIO SECTION

19. What are the two functions of Q_1 in the circuit of Figure 2?

20. What is the frequency relationship between the oscillator signal and the incoming r-f signal in this receiver?

21. Give two functions of the Q_4 stage in the receiver of Figure 2.

22. What type of audio output stage is used in the receiver of Figure 2?

23. What is the function of R_{21} in the circuit of Figure 2?

24. Battery voltage should be measured with the receiver turned on. True or False?

25. Touching a probe to a transistor audio stage generally produces a much louder hum than touching the grid of a vacuum tube audio stage. True or False?

26. If inserting a signal from an audio generator at the base of Q_7 in Figure 2 produces an output, but inserting the same signal at the base of Q_6 does not, which stage do you suspect is defective?

27. In Figure 2, if no sound is produced when the output of an audio generator is applied to the base of Q_8 or Q_9, yet dc voltage measurements on these stages are correct, which of the following might be the cause? (a) Earphone jack not making contact. (b) L_7 primary open. (c) L_6 secondary open. (d) Break in the conductor between emitters and common ground.

28. Temporarily connecting a similar resistor in parallel with bias resistor R_{17} in the circuit of Figure 2 would normally increase the forward bias across the base-emitter junction. True or False?

29. If the Q_7 stage of Figure 2 is open, connecting another resistor in parallel with R_{17} will alter the base voltage but not the collector current. True or False?

30. In Figure 2, what would be the effect on the voltage at the terminals of Q_7 if the primary of L_6 were open?

31. Describe two methods of repairing breaks in printed circuits.

32. In Figure 2, what would be the effect on the voltages at the terminals of Q_7 if the base and collector were shorted?

33. A short in one transistor of a push-pull pair will have no effect on the operation of the other transistor of the pair. True or False?

34. If C_9 were open in the receiver of Figure 2, what symptoms would you expect to find?

35. In Figure 2, if there were no voltages on any terminal of Q_7, Q_6 or Q_5, even with a new battery in the circuit, what component might be at fault?

Component substitution boxes are useful when troubleshooting. A new component can be quickly substituted for the suspected one.

Courtesy Sencore

Q_3. The avc voltage can again be used as an indicator. Keep the input from the signal source at the lowest value which gives a clear indication on your meter.

Possible troubles in this stage include a shorted or open transistor, an open i-f transformer, L_4 or L_3, and the possibility of breaks in the printed circuit conductors. If this stage produces no output, proceed with voltage measurements at the various Q_2 elements.

Assume that you find zero voltage on the collector of Q_2. What parts must you check to locate the trouble? One possibility is the primary of L_4. This is easily checked by measuring the voltage at each terminal of the transformer. The three terminals of the primary should all be at the same potential, in this example about 2.4 volts. If there were no voltage at the center tap, you would suspect the circuit board rather than the transformer because this point should go directly to the negative line. An open in the secondary of L_3 would remove the forward bias on Q_2. This would decrease both the emitter and base voltages of Q_2 and prevent the passage of the i-f signal. Again, an ohmmeter check would point out the trouble.

Checking the Converter

If your checks indicate that the i-f stages are operating normally, yet the receiver does not produce any output when tuned to a broadcast station, the trouble is probably in the converter, Q_1, including the tuning circuits. There are two separate functions to be analyzed with regard to the converter. This stage generates the oscillator signal and combines it with the signal from the antenna to produce the 455-kHz i-f signal. If either of these functions is lacking, the converter will not produce an i-f signal.

Voltage measurements should reveal either an open or shorted transistor if it is defective. Voltage measurements would also show an open in the primary of L_3 above the center tap or in the feedback winding of L_2.

To check the converter, use a signal generator to feed a modulated 455-kHz signal to the base of Q_1. If this signal comes through properly, transistor Q_1 and transformer L_3 are all right.

Next, set the signal generator for a modulated r-f signal near the center of the broadcast band. Loosely couple the signal generator to the antenna. Set the radio dial to agree with the frequency shown on the generator. If the modulating signal produces an audio tone from the speaker, the converter is operating properly.

If you get no output indication in this check, the antenna circuit may be defective or the oscillator may not be operating. To check the oscillator, measure the emitter voltage of Q_1. With a screwdriver or other metal object, short oscillator tuning capacitor C_{12B} and watch for a change in emitter voltage. If the oscillator is working, this voltage will change when the oscillator is disabled by the short.

If the oscillator section is not working and the voltages of Q_1 appear near normal, the trouble may be in L_2, the secondary of L_1, C_{12B} or C_1. An ohmmeter can be used to check L_2 and the secondary of L_1. Both of these coils should show very low dc resistance. Taps 3, 4 and 5 on L_2 should read a very low resistance with respect to ground. The secondary of the antenna coil does not connect directly to ground. A short from stator to rotor of C_{12B} or across its trimmer capacitor would prevent oscillation. Either an open or short in capacitor C_1 would also prevent oscillation.

If the oscillator is operating, yet no broadcast signals are reproduced, your search can be confined to antenna coil L_1 and its tuning capacitor C_{12A}. Either an open or a short in the coil or a shorted capacitor, C_{12A}, could prevent signals from being received.

DISTORTED AND INTERMITTENT OPERATION

Throughout this lesson we have assumed that the radio requiring service is entirely inoperative when it comes to you. This is the most common situation. There are service jobs, however, where the symptom is other than a dead receiver.

For example, there are many cases of trouble which cause low gain rather than total failure. There may be cases of intermittent operation where the radio works well part of the time and then goes dead or loses gain. Occasionally, there will be radios with different types of distortion, such as raspy sound, or generally poor quality output.

All these situations are more troublesome to the serviceman than are the total failure cases. Intermittent conditions are usually the hardest to locate and correct because the receiver may operate normally for a long time before the intermittent occurs. If the cost of the radio is small, the time required to find the intermittent trouble may not be justified. You should explain this to the customer.

There are a number of intermittent sets which go abruptly from fully normal operation to no operation. Sometimes this occurs with movement of the chassis and sometimes only after a certain period of operation.

If the intermittent condition seems to depend on some movement or strain of a printed circuit board, the cause is usually a faulty connection on the board. This may be a bad solder joint or a hairline break in one of the connecting paths on the board. If warping the board or applying pressure at any point disables the receiver, you should look for such connections. It is sometimes faster to resolder all connections in the suspected area than to search for the fault. Even a minute break in the foil of a printed circuit can result in intermittent operation. Sometimes these breaks are invisible to the unaided eye.

Intermittent operation is often the result of changes in characteristics of various components with heat. In transistorized receivers the transistors themselves are prime suspects when this sort of interruption occurs. Because transistors do not radiate any great amount of heat, there is seldom enough expansion or contraction on the board to cause problems. But the amount of current through the transistors does vary with temperature, and overheating a transistor may have very marked effects on its operation.

Most circuits include elements in the biasing arrangement to prevent increases of transistor current as the operating temperature of the device increases. A resistor in the emitter circuit of a common emitter amplifier is there for this reason. If the emitter bypass capacitor is shorted or leaky, it lowers the effectiveness of this resistor and may cause problems as the transistor temperature increases.

Many circuits also employ a relatively low resistance from base to ground to improve temperature stability. If this resistance is open, stability problems may develop.

When a radio works properly from a cold start but fails after a period, always check for a change from normal resistance between either the base or emitter and ground. You can sometimes speed up the service time by shining a lamp on the circuit to raise its temperature. You may also keep the radio turned on while you go about other service jobs, and check it when the intermittent shows up.

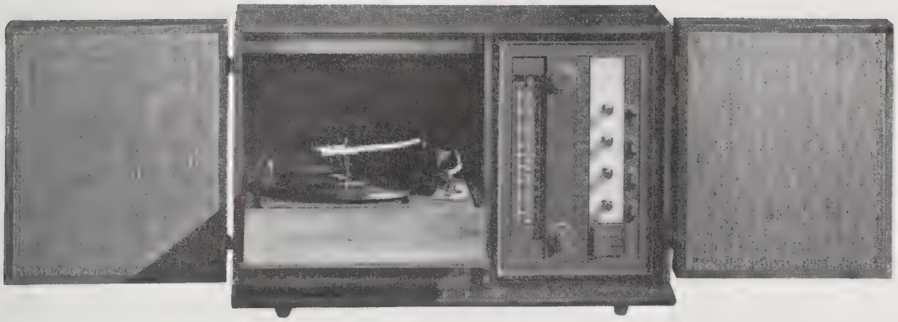
Less common complaints when a radio is brought in for servicing are such things as distortion and lack of selectivity or sensitivity. Misalignment and tracking problems between tuned circuits are likely to be the cause of either selectivity or sensitivity problems.

Audio distortion may be caused by low battery voltage or improper biasing. If the power output stage uses a push-pull arrangement, the two transistors may not be well balanced. If you replace one of the output transistors, it is usually best to replace both to avoid this problem. Output transistors are often sold in matched pairs for push-pull use.

A damaged speaker is also a frequent source of distortion. Testing the output at the earphone jack may show whether the problem is in the speaker. A test speaker with characteristics similar to those of the original may be substituted to check the condition of the original speaker.

Leaky coupling capacitors ~~can also cause~~ distortion because they alter bias levels and may shift the operating point of a stage to a nonlinear portion of its characteristic curve.

Most radios of the type we are discussing in this lesson are not high-fidelity instruments. To attempt to get good bass response from the small speakers used is a waste of time.



This modern radio phonograph usually includes both an AM and an FM receiver. Servicing the FM section is similar to that of servicing the AM section except for the differences in operating frequency and detector circuits.
Courtesy General Electric Co.

High-frequency response is also limited because of the quality of the audio transformers used. The best you can hope to do is restore the quality to the level that existed when the radio was new.

COMPLETING THE REPAIR

Up to this point we have said little about performing the actual repair work when the trouble is located. This is a necessary part of the job and one that you must learn to do neatly and efficiently. The average serviceman with a little experience becomes quite proficient at this. However, the area in which the good man can most easily be distinguished from the average is in his ability to find the trouble with the least delay.

When removing a defective part from a printed circuit board, take care not to damage the board. Don't worry about salvaging the part. Cut the leads and get the part out. Cleaning used solder from the mounting holes usually requires access to both sides of the board. In cases where one side is not accessible, it is sometimes best to leave the leads of the original part in the holes and solder the new part to these leads.

Avoid overheating printed circuit boards because the copper foil that serves as the connecting leads may peel off the mounting surface. Where hairline cracks in these foil leads occur, you can sometimes make a simple repair by flowing solder over the break. Where extensive breaks occur, you can solder a short length of wire over the break.

When selecting replacement parts, be sure that the new part is electrically equivalent to the original. Also, make sure its physical size will permit it to be used in the space provided. On some circuit boards there is crowding at points, which severely limits the size of any replacement parts.

If you find damaged components, always check for the possible cause of failure. A burned resistor, for instance, is usually the result of some other trouble which caused excessive current through the resistor. To replace the resistor without finding the original trouble is no cure.

Consider also the effect of any failure as well as its cause. A shorted filter capacitor in the power supply may have caused the trouble originally. This, in turn, might have seriously overheated the filter resistor and possibly put considerable strain on the rectifier. Never stop checking after locating one bad component. Search further, until you are satisfied that it is the only bad component or that you have found all others.

As a final touch, clean the unit and make sure it presents a good appearance when you return it to the customer. This simple gesture takes very little time and effort, yet it pays dividends in customer satisfaction. In receivers that use pilot lamps, replace any burned-out lamp. Also check the condition of the various control knobs, calibration of the tuning dial, etc. These little touches go a long way toward instilling customer confidence in your work.

RECEIVER ALIGNMENT

As previously mentioned, when components in the i-f and r-f circuits are replaced, alignment may be necessary. The modulated signal generator used for troubleshooting may be used for alignment. A VTVM or other high impedance meter may be used as an output indicator during the alignment.

To illustrate the alignment process, let's go through the complete alignment of the receiver of Figure 1. When working on a transformerless set such as this one, an isolation transformer should be used. The voltage on the avc line may be used as an indication of signal strength during alignment. The VTVM can be connected to the junction of R$_3$ and C$_8$. Under no-signal conditions, this point will have a very small negative voltage, usually less than one volt. As signal strength increases, the avc voltage will become more negative. The last i-f amplifier stage is aligned first. The signal generator output frequency should be set to the exact i-f frequency, 455 kHz in this example, and the normal modulation applied. The signal generator ground lead should be connected to the common point and the "hot" lead to the grid of V$_2$. The signal generator output should be set to a point where it produces an increase in the voltage. Then, both the primary and secondary tuning slugs in T$_2$ should be adjusted for maximum indication on the meter. It may be necessary to reduce the signal generator output to keep from overloading the receiver. Always use as little output from the generator as possible to give a reliable indication.

It is important that the correct alignment tools be used. In this example, the i-f transformer is tuned with slugs in the primary and secondary windings. Improper tools can damage the cores. Also make sure the alignment tool is nonmetallic. A metal tool can affect the tuning. Some of the older receivers used variable capacitors to tune the i-f transformers. An insulated tool with a metal tip is suitable here. Because B+ is applied to the tuning capacitor, make sure you do not touch it or short it to the transformer case.

Go back over the adjustment on the last i-f transformer several times to be sure that you have it peaked. Now move the signal generator hot lead to the grid of V_1, pin 7. With some receivers it is necessary to disable the local oscillator during i-f alignment. This can be done by shorting C_{1B}. With the generator connected to V_1, adjust the primary and secondary of T_1 to obtain a maximum indication on the avc meter. Again, keep the output of the signal generator as low as possible to prevent overloading the receiver. Go back over the primary and secondary adjustments several times to make sure they are peaked, as they interact to a certain extent. This completes the i-f alignment.

The next step is to align the local oscillator. Set the main tuning dial to 600 kHz. Also set the signal generator to 600 kHz. If there were a short placed across the oscillator capacitor during the i-f alignment, remove it. The quickest way to couple the signal into the receiver front end is to make a coupling coil consisting of about 50 turns of regular insulated hookup wire about 4 inches in diameter. Connect the signal generator output to this coil and place the coil close to the antenna coil. In some situations it may be possible to just place the signal generator hot lead near the antenna coil and get enough signal into the receiver. With dial and generator set to 600 kHz, adjust the slug in the oscillator coil to obtain maximum output on the meter. Again, keep the generator output as low as possible to prevent overload.

Now set the signal generator and tuning dial to 1400 kHz. Adjust both the oscillator and tuning capacitor trimmers T_A and T_B for maximum output. Reset the main dial and generator back to 600 kHz and readjust L_2 for maximum output. Go back over both adjustments to ensure that they are both correct. This completes the alignment. An "on the air" check of local stations will verify the alignment and tracking. The frequencies given in this example are typical but may vary from receiver to receiver. If at all possible, consult the manufacturer's alignment instructions. In some instances it may not be necessary to do a complete alignment. For example, if T_2 is replaced it is generally only necessary to align that stage. Because the whole process

STEP	GENERATOR FREQUENCY	CONNECT GENERATOR TO	SET DIAL AT	ADJUST	NOTES
1	455 kHz	V_2, PIN 1	———	T_2, SEC+PRI	SHORT C_{1B}
2	455 kHz	V_1, PIN 7	———	T_1, SEC+PRI	SHORT C_{1B}
3	600 kHz	COUPLING LOOP	600 kHz	L_2	
4	1400 kHz	COUPLING LOOP	1400 kHz	$T_A + T_B$	

NOTES:
1. CONNECT VTVM TO AVC LINE FOR OUTPUT INDICATION
2. REPEAT ALL ADJUSTMENTS SEVERAL TIMES TO BE SURE THEY ARE PEAKED
3. KEEP GENERATOR OUTPUT AS LOW AS POSSIBLE TO AVOID OVERLOAD

Figure 3

takes but a few minutes, you might go over the entire receiver and quickly retune it. Figure 3 shows the entire alignment process in chart form. Charts such as these are included in the service literature and should be followed if possible.

Alignment of the transistor receiver of Figure 2 would follow the same plan. However, there is usually only one adjustment on each of the i-f transformers. The secondaries are not normally tuned because they are working into such a low impedance. Connection of the signal generator to a transistor receiver constructed on a printed circuit board is often difficult or impossible. The coupling coil described earlier can be used for this purpose. Just lay the coil over the receiver. As always, be sure to use as low a generator output as possible so as not to overload the receiver.

The receiver avc line may also be hard to connect to in a printed circuit receiver. The simplest method is to connect the meter to the speaker terminals. Set the meter to measure ac voltage and place it on the lowest range. An ac VTVM can also be used for this purpose. In fact, most transistor receiver manufacturers specify this method of alignment indication.

Because most of the i-f transformers in transistor receivers are small, use care when adjusting the slugs. It is quite easy to damage the slugs. Always use the proper alignment tool. Once the alignment has been completed, the slugs can be sealed, using wax from a small candle. Use just a drop; do not fill in the entire slug. This may make it difficult or impossible to remove the wax if the unit has to be aligned again.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

SERVICING A TRANSISTOR PORTABLE RADIO

CHECKING THE I-F SECTION

CHECKING THE CONVERTER

DISTORTED AND INTERMITTENT OPERATION

COMPLETING THE REPAIR

RECEIVER ALIGNMENT

36. To which stage or stages in the receiver of Figure 2 is avc voltage applied to control the gain?

37. In Figure 2, an open in the L_5 primary between the center tap and the lower end of the primary would result in a complete lack of collector voltage on Q_3. True or False?

38. In Figure 2, assume that Q_2 is shorted internally from base to collector. What voltages would you read at the various elements of Q_2?

39. If C_1 of Figure 2 were shorted, how would the voltage at the base of Q_1 be affected?

40. If C_{12A} of Figure 2 were shorted, would the bias on the base of Q_1 be affected?

41. If tapping on a printed circuit board causes a radio to cut off, what is a probable cause?

42. Intermittent operation may result from the overheating of various components in the circuit. True or False?

43. List two important considerations in selecting a replacement part.

44. If the filter resistor in the receiver of Figure 1 were damaged by excessive current, which of the following might be the cause? (a) T_3 open. (b) C_{5A} shorted. (c) C_4 open. (d) T_1 open.

45. The first step in the complete alignment of a superheterodyne receiver is the alignment of the (a) local oscillator, (b) first i-f, (c) last i-f.

46. The output from the signal generator should be set as low as possible. True or False?

47. The oscillator coil slug in the receiver of Figure 1 is set at the __________ end of the band.

48. The mixer trimmer capacitor, T_A, in the receiver of Figure 1 is set at the __________ end of the band.

49. Both the primary and secondary of the i-f transformer in transistor receivers are normally tuned. True or False?

50. The most convenient alignment indication point in a transistor receiver is the (a) speaker, (b) avc line, (c) battery voltage.

SUMMARY

In servicing AM broadcast radio receivers, whether they are of the tube or transistor variety, the most essential item is a logical approach to the problem. A step-by-step routine of tests designed to locate first the defective stage and then the faulty component is required. Begin with the known symptoms of the trouble. Determine whether or not power can safely be applied, and then proceed to eliminate sections of the receiver from further tests.

In tube equipment, many of the problems are caused by tube failure. Thus, tube substitution is recommended as an early check. In transistor receivers, transistor failure is much less likely, so this step is not included until the defective stage is isolated.

After tube checks and a visual inspection, one of the first steps is to insert an audio signal at the volume control. This serves to divide the set roughly in half and will reveal which half contains the defect. If no sound can be heard when an audio signal is applied to the volume control, the trouble is either in the power supply or the audio portion of the receiver including the speaker. If this signal is heard, checks will be confined to the radio-frequency portion of the radio.

To further isolate the trouble, move the signal source one stage at a time toward the speaker if audio trouble is indicated, or toward the antenna if r-f trouble is indicated. When the trouble is in the r-f portion of the receiver, you need a modulated r-f generator as a signal source, and you must adjust the input frequency to the appropriate frequency for the stage you are testing.

During i-f and r-f checks, you can use both the speaker audio output and the avc voltage as indicators of correct or faulty performance. The faulty stage is the stage nearest the speaker which will not pass the signal.

When the defective stage in either a tube or transistor radio has been located, use voltage measurements and resistance measurements in that area to pinpoint the defective part.

You should establish this plan for troubleshooting firmly in your mind. The secret to fast, effective troubleshooting is the application of a logical approach. You will improve with experience, but you will do well from the start if you stick to the basic plans presented here.

PRACTICE EXERCISE SOLUTIONS

1. True—Each test should suggest what to do next.

2. Yes—Because there is no evidence of overheating, there should be no ill effects from applying power.

3. No—Applying power may cause further damage. You should begin this job with ohmmeter tests.

4. (b) Test the tubes.—There will be no B+ if the tubes are not operating, and alignment is impossible unless the receiver is operating.

5. T_2 is always tuned to the i-f frequency, or 455 kHz, no matter what frequency is tuned on the dial.

6. C_{5A} and C_{5B} are the power supply filter capacitors. They serve to smooth out the dc used by the receiver.

7. V_3 functions as a diode detector and an audio voltage amplifier.

8. Series.—This is typical of the ac-dc type receiver.

9. The radio would be completely dead.—All filaments go out when any one in the series string is open.

10. Watch the new rectifier closely when power is applied. Turn off the receiver and perform resistance tests if the plates of the rectifier turn red.

11. A loud hum.—Oscillator trouble would not affect the audio section of the receiver.

12. If the tube were not conducting, there would be no current through the cathode resistor and no voltage at the cathode.

13. There would have been zero voltage at the plate. This should have led you to the open, which could be detected by an ohmmeter test.

14. The short across the capacitor would disappear. However, the short would remain on the 90-volt B+ line.

15. The primaries of T_1 and T_2, and the screen grids of V_1, V_2 and V_4. A short of any of these points would read as a short at C_{5A}.

16. On the secondaries of either T_1 or T_2, the ungrounded end of the volume control, or the junction of R_3 and C_2.—Note that while the secondary of T_2 and the ungrounded end of R_4 are the same point electrically, they are not at the same location in the receiver.

PRACTICE EXERCISE SOLUTIONS (Continued)

17. (b) C_4 open.—This would prevent audio from reaching the grid of V_3. Neither a weak 12BE6 nor an open T_1 would affect the audio section, and to have C_{5B} shorted would mean that B+ was not normal.

18. (d) T_1 open.—No i-f signal reaches the detector. Either V_4 not operating or C_4 open would result in no audio. If C_{5B} were shorted, the B+ voltage would not be normal.

19. Q_1 functions as an oscillator and converter stage, generating the oscillator signal and combining it with the incoming r-f signal to produce the i-f signal.

20. The oscillator signal is 455 kHz above the incoming r-f signal.

21. Q_4 is a diode detector, and also provides avc voltage for the Q_2 stage.

22. The receiver uses a push-pull output stage, with the out-of-phase driving signals produced by a tapped driver transformer.

23. It provides negative feedback from the output stages to the input of Q_5. This is done to reduce distortion.

24. True—A weak battery may appear to have normal voltage until a load is applied.

25. False—The lower input impedance in the transistor circuit tends to reduce the signal amplitude.

26. Probably Q_6.—Another possibility is the coupling capacitor between these two stages.

27. (a) Earphone jack not making contact (or L_7 secondary open).—Either of the other conditions mentioned would not only prevent an audio output, but would also affect the voltage readings on Q_8 and Q_9.

28. True—The parallel resistor lowers the resistance between the base and the supply terminal, and therefore increases the forward bias.

29. False—If the transistor is open, there will be no current through R_{17}, so changing its resistance will not change the base voltage.

30. The collector voltage would drop to zero. The base and emitter voltages would be unchanged.

31. For small breaks, simply flow solder across the break. For larger breaks, bridge a piece of wire across the break and solder it to the foil strips on both sides of the break.

PRACTICE EXERCISE SOLUTIONS (Continued)

32. All voltages around Q_7 would be lowered. Most of the supply voltage would be dropped across R_{20} and L_6.

33. False—The shorted transistor will alter the operating voltages on the other transistor, and thus prevent normal operation.

34. The audio section would work from Q_7 on, but no signal could get to the base of Q_7. The voltages on Q_7 would be approximately normal.

35. R_{20} may be open, C_8 may be shorted or the switch S_1 is defective. An ohmmeter will indicate the defective component.

36. To the Q_2 stage only.

37. False—The upper half of the primary supplies the collector voltage to Q_3.

38. The voltages on the base and collector would be identical. They would be less-than-normal collector voltage. The emitter voltage would be more negative than normal.

39. The base voltage on Q_1 would decrease to near zero. The oscillator would not operate and R_1 would be shorted out.

40. No—Shorting C_{12A} prevents signals from being received, but does not affect the bias voltage of Q_1.

41. Either bad solder connections between the board and components mounted on it or a hairline crack in the conductors on the board.

42. True—Overheated components often change value sufficiently to cause the circuit to operate improperly.

43. The replacement part must be electrically equivalent to the original. Also, the physical construction of the replacement must be such that it will mount conveniently in place of the original.

44. (b) C_{5A} shorted.—Excessive current through R_9 indicates a short beyond the resistor. The open conditions indicated in (a), (c) and (d) would not increase current.

45. (c) last i-f.—Always start with the last i-f and work towards the front end.

46. True—This prevents receiver overload.

47. low—600 kHz is a typical frequency.

48. high—1400 kHz is a typical frequency.

PRACTICE EXERCISE SOLUTIONS (Continued)

49. False—The secondaries are generally not tuned because of the low input impedance of the following stage.

50. (a) speaker.—The meter should be set up to measure ac volts on the lowest range.

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ONE OF THE
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7515A
EXAMINATION CHECK SHEET

7515A

1. B - IN FOLLOWING A LOGICAL TROUBLESHOOTING PLAN, THE SERVICEMAN -- LETS THE RESULT OF ONE TEST DETERMINE WHAT WILL BE TESTED NEXT.
To locate the trouble in the least amount of time, each step should point the way to the next step.

2. B - IF THE 12BA6 FILAMENT IS OPEN IN THE CIRCUIT OF FIGURE 1, -- THE VOLTAGE ACROSS IT WILL BE EQUAL TO THE LINE VOLTAGE.
When an open occurs in a series circuit, the supply voltage appears across the open.

3. C - IN A SUPERHETERODYNE AM BROADCAST RECEIVER, THE LOCAL OSCILLATOR NORMALLY OPERATES -- ABOVE THE FREQUENCY OF THE INCOMING SIGNAL.
To permit practical values of L and C in the local oscillator circuit, it operates at the i-f above the incoming signal frequency.

4. D - IN A PROPERLY OPERATING TRANSISTOR STAGE, ALTERING THE BASE BIAS VOLTAGE SHOULD -- CHANGE THE COLLECTOR CURRENT.
A change in bias will always change the collector current.

5. A - WHEN AN AUDIO SIGNAL INJECTED AT THE VOLUME CONTROL OF A RADIO PRODUCES ADEQUATE SOUND FROM THE SPEAKER, YOU MAY ASSUME THAT -- THE POWER SUPPLY AND AUDIO AMPLIFIERS ARE WORKING PROPERLY.
If the audio amplifier is operating, you can assume that the power supply is all right.

6. A - IF A RECEIVER HAS AN OPEN TRANSISTOR IN THE FIRST I-F STAGE, -- A MODULATED R-F SIGNAL FED TO THE ANTENNA WOULD PRODUCE NO OUTPUT.
With the first i-f transistor open, no signals are going to pass through this stage from the converter stage.

7. A - ASSUME THAT THE Q_3 STAGE WILL NOT PASS AN I-F SIGNAL. YOU MEASURE THE EMITTER VOLTAGE AND FIND IT MUCH LOWER THAN SPECIFIED. A POSSIBLE CAUSE WOULD BE -- AN OPEN IN THE L_4 SECONDARY.
An open L_4 secondary would remove the forward bias on Q_3. Therefore, with only leakage collector current, the voltage drop across R_{10}, as well as the emitter voltage, is greatly reduced.

8. B - IF L_2 IN THE CIRCUIT OF FIGURE 2 HAS AN OPEN BETWEEN TERMINALS 3 AND 4, -- INJECTED I-F SIGNALS WILL PASS THROUGH THE Q_2 STAGE.
With an open in L_2 the local oscillator will be inoperative. However, the Q_2 stage will not be affected and can still pass i-f signals.

9. B - IF C_{12B} IN THE RECEIVER OF FIGURE 2 WERE SHORTED TO GROUND, -- THE LOCAL OSCILLATOR WOULD NOT OPERATE.
C_{12B} is the local oscillator tuning capacitor. If shorted, it would short the tank circuit, stopping oscillation.

10. A - IF THE PRIMARY OF AUDIO INTERSTAGE TRANSFORMER L_6 OF FIGURE 2 WERE OPEN, THERE WOULD BE NO AUDIO BECAUSE -- Q_7 WOULD HAVE NO COLLECTOR VOLTAGE.
The Q_7 stage receives the collector voltage through the L_6 primary. If the L_6 primary opens, there will be no Q_7 collector voltage and thus no Q_7 collector current.

QUESTIONS

IMPORTANT—These instructions **MUST** be accurately followed to avoid loss, or errors in grading.

Indicate your answer on this sheet by filling in the box for the most correct answer to each question, as illustrated in the example below.

When all questions have been answered, place the answer card in the proper position to line up the boxes on the card with the boxes on the sheet.

Next, copy the complete lesson code into the space provided on the card, and fill in the answer boxes to correspond with those previously filled in on this sheet.

Before mailing, be certain your correct student number, name and address appear on the card.

LESSON CODE
7515A

Example: An animal found in many African swamps and rivers is the (A) polar bear. (B) crocodile. (C) walrus. (D) whale.

A ☐
B ■
C ☐
D ☐

1. A ☐ B ☒ C ☐ D ☐

In following a logical troubleshooting plan, the serviceman
(A) always begins with voltage measurements. (B) lets the result of one test determine what will be tested next. (C) always begins with resistance measurements. (D) always begins with an r-f alignment.

2. A ☐ B ☒ C ☐ D ☐

If the 12BA6 filament is open in the circuit of Figure 1,
(A) the voltage across it will be zero. (B) the voltage across it will be equal to the line voltage. (C) the voltage across all the other filaments will increase. (D) only that tube filament will not be lit.

3. A ☐ B ☐ C ☒ D ☐

In a superheterodyne AM broadcast receiver, the local oscillator normally operates
(A) at the i-f frequency. (B) below the frequency of the incoming signal. (C) above the frequency of the incoming signal. (D) at the frequency of the incoming signal.

4. A ☐ B ☐ C ☐ D ☒

In a properly operating transistor stage, altering the base bias voltage should
(A) have no effect on collector current. (B) have no effect on emitter-to-base current. (C) always change the emitter voltage. (D) change the collector current.

5. A ☒ B ☐ C ☐ D ☐

When an audio signal injected at the volume control of a radio produces adequate sound from the speaker, you may assume that
(A) the power supply and audio amplifiers are working properly. (B) the i-f section is working properly. (C) the local oscillator is not working. (D) the output transformer is defective.

6. A ☒ B ☐ C ☐ D ☐

If a receiver has an open transistor in the first i-f stage,
(A) a modulated r-f signal fed to the antenna would produce no output. (B) all collector voltages would measure low. (C) audio signals injected at the volume control would produce no sound. (D) avc voltage would vary normally, but no stations would be heard.

7. A ☒ B ☐ C ☐ D ☐

Assume that the Q_3 stage in Figure 2 will not pass an i-f signal. You measure the emitter voltage and find it much lower than specified. A possible cause would be
(A) an open in the L_4 secondary. (B) a shorted L_4 secondary. (C) a collector-to-base short in Q_3. (D) an open in R_{10}.

8. A ☐ B ☒ C ☐ D ☐

If L_2 in the circuit of Figure 2 has an open between terminals 3 and 4,
(A) the oscillator frequency will increase. (B) injected i-f signals will pass through the Q_2 stage. (C) the oscillator frequency will decrease slightly. (D) the emitter of Q_1 will become more negative than the base.

9. A ☐ B ☒ C ☐ D ☐

If C_{12B} in the receiver of Figure 2 were shorted to ground,
(A) the battery would be shorted and run down. (B) the local oscillator would not operate. (C) all bias voltages in the circuit would be abnormal. (D) strong signals would still be received.

10. A ☒ B ☐ C ☐ D ☐

If the primary of audio interstage transformer L_6 of Figure 2 were open, there would be no audio because
(A) Q_7 would have no collector voltage. (B) Q_8 and Q_9 would not be properly biased. (C) Q_6 would not conduct. (D) there would be no Q_7 emitter-base current.

SERVICING AUTOMOBILE RECEIVERS

7520

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PRINTED IN USA

This automobile receiver is designed to receive regular and stereo FM broadcasts. The under-dash mounting arrangement makes removal and replacement a simple matter.

Courtesy Motorola, Inc.

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Formula for failure: Try
to please everybody.
—H. B. Swope

SERVICING AUTOMOBILE RECEIVERS

One of the most common types of radios in use today is the automobile radio. Millions of new automobiles are purchased in the United States each year, and the number is expected to rise from year to year. Most automobiles are equipped with radios as original equipment or have a radio added after purchase.

The cost of an automobile radio is sufficient to warrant any necessary repair. Most auto radios are well constructed, and are capable of good reception when working properly. In addition to conventional AM radios, there has been an increase in the number of combination AM-FM and FM stereo receivers and cartridge tape players in use.

All automobile radios on the market today are solid state. The tube-type auto radio largely disappeared from the market. The obvious advantages of smaller size, lower voltage requirement, smaller battery drain and increased dependability have all contributed to this trend.

There are several common problems which can be solved without removing the radio. Audio noise, but no signal, often means that the antenna plug has vibrated out of its jack. A test antenna may be tried if this test fails. No power could mean a blown fuse or an open power lead. Raspy sound might be traced to a defective speaker; a test speaker will give the answer.

The problems of troubleshooting auto radios are largely the same as those encountered in servicing any other transistorized radio. There are, however, a few special considerations which must be considered before examining the troubleshooting procedure. These include the mechanical problems of removing and installing the radio, and the necessity for supplying bench power to the radio when troubleshooting in the shop.

INSTALLING AND REMOVING AUTO RADIOS

Most auto radios are designed and packaged for mounting either in or immediately below the dashboard of the car. In some cars their removal and installation is a major portion of the repair job.

Always carefully disconnect all external connections before attempting to physically remove the radio. External connections to an auto radio include the power cable from the battery, an antenna lead, and usually a set of speaker leads.

Next, inspect the physical mounting arrangement behind the dashboard carefully. This may require that you "crawl under" the dash to locate the mechanical mounting points. A flashlight or trouble light will help in this inspection. If the manufacturer's service manual is available, it may include instructions for removing the radio.

Mounting hardware differs considerably in different cars, and between factory installed receivers and those custom installed after the car is delivered. The through-the-dash type mounting shown in Figure 1 is the most common type of installation. To remove such a radio, first remove the tuning and volume control knobs, and the hex nuts which hold the shafts of the controls to the dashboard. The rear of the radio is usually held to the dashboard by some form of bracket either connecting upward or extending back to the fire wall. Some radios are supported on both sides, and some on only one side. In order to prevent loss of knobs or hardware, it's a good idea to put these parts in a small plastic bag and leave them in the customer's glove compartment.

Always check for any obstructions before removing the radio. In some instances it may be necessary to remove or shift other units under the

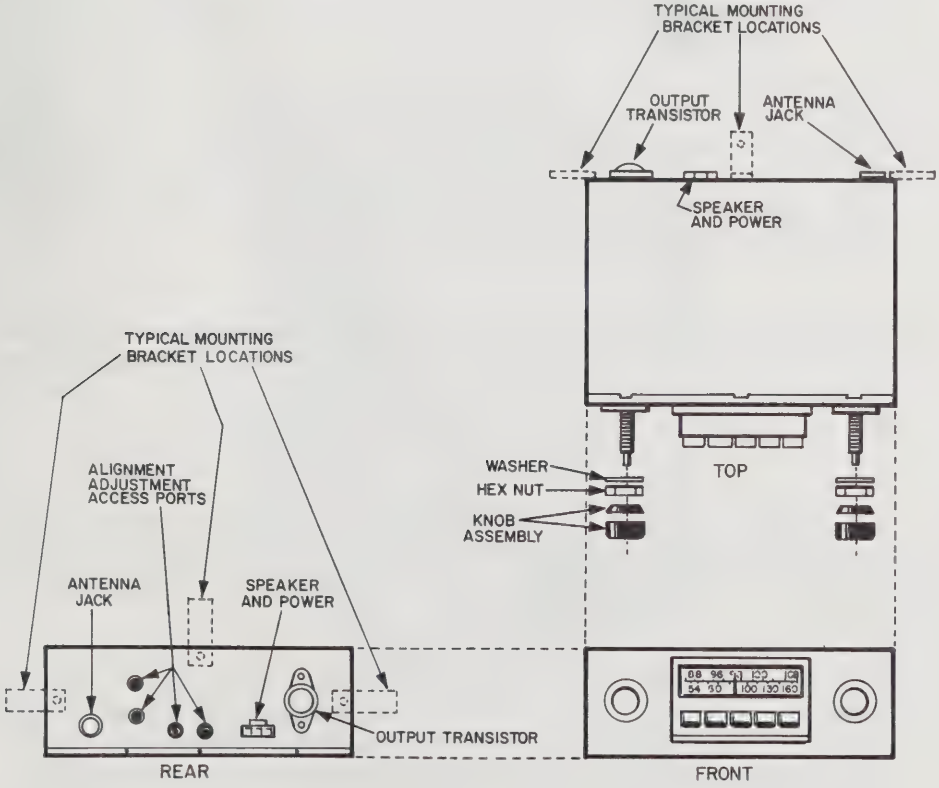


Figure 1

dashboard (defroster hoses, instrument wires, glove compartments, etc.) before the radio itself can be freed. On air conditioned cars, it is often necessary to remove duct work and air hoses. Simply removing the glove compartment may also provide a radio exit path. Other alternatives include removal of the dashboard section that surrounds the radio or removal of the entire top half of the dashboard. The latter is probably necessary when the front speaker is defective.

Whenever cables or hoses are disconnected, they must later be replaced exactly as they were found, or unexpected problems could be created. For example, reversing two seemingly identical trunk release hoses will render that device inoperable. Never let a cable "snap back" when it's released. The sudden strain release may cause the cable to lodge in an inaccessible location, forcing you to waste time retrieving it.

Receivers mounted below the dashboard are often supported at both the front and back by mounting brackets that bolt to the dash and the radio. In most situations these radios are easier to remove than the through-the-dash models.

BENCH POWER FOR AUTO RADIOS

Auto radios are designed to be powered directly from the car's battery. No voltage higher than the battery voltage is normally required. The current requirements vary from about .2 amp to 1 amp for 12-volt operation and slightly higher when designed for 6-volt operation. Tube-type receivers have a much higher current requirement.

An automobile battery and provisions for recharging it can be used when the radio is operated on the service bench. However, many servicemen prefer to use some form of battery eliminator which draws power from an ac source. Suitable supplies for this purpose are available commercially.

The supply used needs both good regulation and good filtering. If the filtering is not adequate or the supply has high internal resistance, a feedback condition known as "motorboating" often arises.

Figure 2 shows a schematic diagram of an ac power supply designed for bench operation of car radios. When the voltage switch, S_2, is in the 6-volt position, as shown, D_1 and D_2 operate as a full-wave rectifier and D_3 and D_4 are not connected into the circuit. When switch S_2 is in the 12-volt position, all four diodes operate as a bridge rectifier, and twice the output voltage is produced.

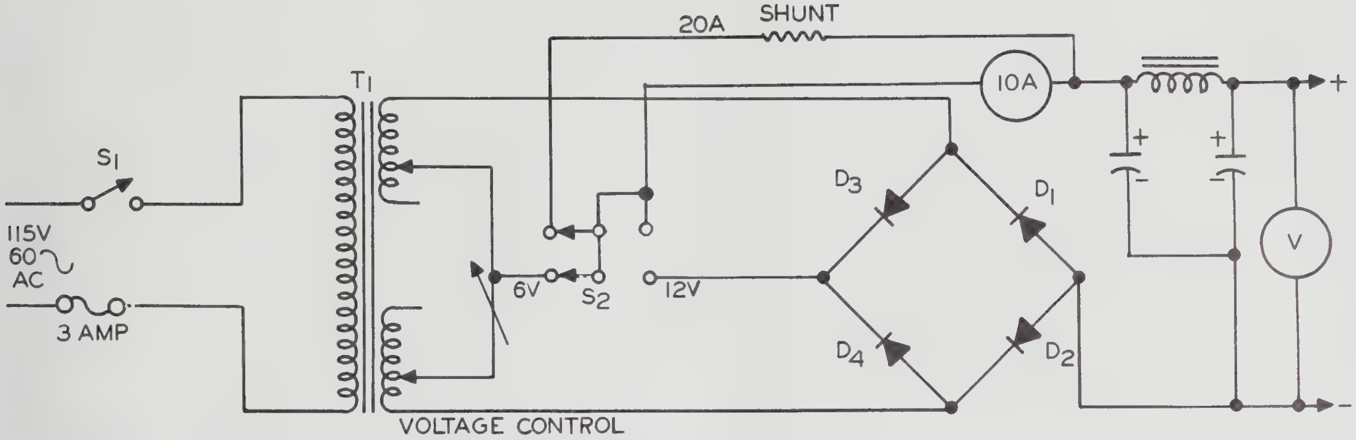
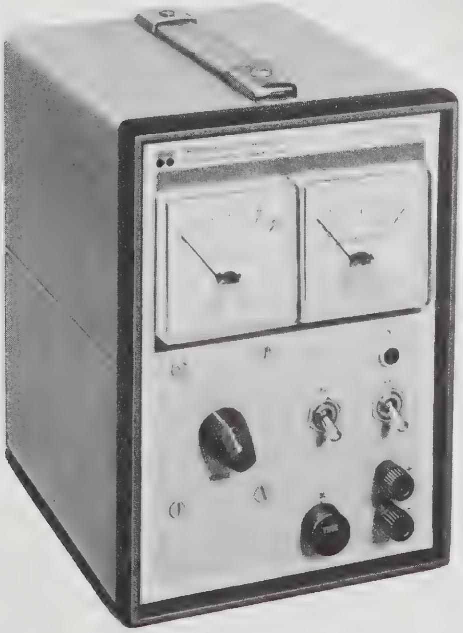


Figure 2

The voltage in either the 6- or 12-volt position is variable by means of the movable contact on the two secondary windings of T_1. The percentage change obtained by shifting this contact is the same in either voltage range. A voltmeter and an ammeter monitor the output of the supply. In the 6-volt position a shunt is connected across the ammeter to increase its full-scale reading to 20 amps. The bench supply must be very well filtered and should have as low an output impedance as possible. If the supply is not variable, it



A well-filtered and regulated power supply is essential for bench repair of automobile receivers. The unit shown above employs special power supply filter components to obtain a low ripple level with good regulation.
Courtesy Precise Electronics, Inc.

should have electronic voltage regulation because the loads presented by various radios vary widely.

AM AUTOMOBILE RADIOS

The circuits employed in most AM car radios differ in only a few respects from home-entertainment transistor radios. Most auto radios employ an r-f stage ahead of the mixer. This stage is often not present in home radios. Nearly all car radios use permeability tuning rather than variable tuning capacitors. In such an arrangement, the frequency of a tuned circuit is varied by moving the slug in a coil. The coils are arranged to permit gang tuning of the r-f stage, the oscillator and the mixer input. Permeability tuning is used because of its high mechanical stability.

Current mode car radios for the AM broadcast band generally use 262 kHz for the i-f as compared to 455 kHz for home radios. This is now standard in nearly all new models, though older sets coming in for service may still have a 455 kHz i-f. The choice of the lower i-f frequency permits higher gain per stage in the i-f amplifiers. It is not used in most simple home radios because of image problems when no r-f stage is included in the tuner.

A majority of car radios involves some form of pushbutton tuning. The buttons are preset to local stations so that the driver can switch stations without distraction from his driving. Most such arrangements are mechanical rather than electronic, and actually move the same coil slugs that are tuned with the main tuning dial.

In most pushbutton tuned car radios it is a simple matter to set the buttons to the desired stations. The button is first pulled out toward the driver, the station is carefully tuned in with the manual tuning knob, and then the button is pushed in firmly. When the button is used thereafter, it will return the tuning to the same point of the dial at which it was set.

Positive and Negative Ground Systems

In most automobiles the negative terminal of the battery is connected to the metal frame or chassis, giving a negative ground. In others the positive battery terminal is grounded. It is essential in bench checking any auto radio that the voltage supply have the proper polarity—that it agrees with the battery polarity in the car in which the radio is used.

Some radios are sold for installation in any make of car. These units usually have alternate power input connections for use with either positive or negative ground systems. Figure 3 shows an example of this type of system, where a jumper plug is used to connect the common lead of the circuit (⏚) and the actual ground lead which connects to the radio case and the chassis of the vehicle (⊥).

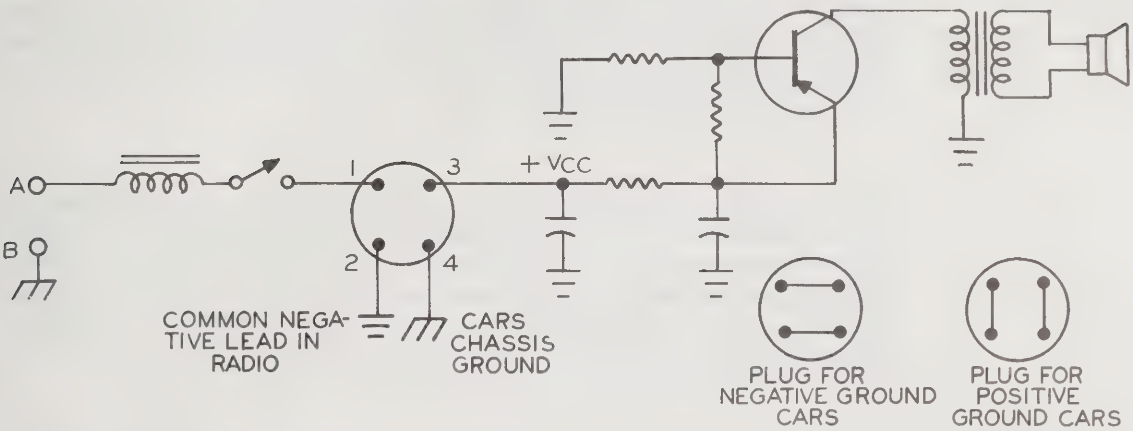

A
B
1
2
3
4
+ VCC
COMMON NEGATIVE LEAD IN RADIO
CARS CHASSIS GROUND
PLUG FOR NEGATIVE GROUND CARS
PLUG FOR POSITIVE GROUND CARS

Figure 3

A single PNP transistor is shown in Figure 3, but all the transistor emitters in the radio are connected to this V_{CC} voltage supply point. With the jumper plug in the position indicated for negative ground, terminals 1 and 3 of the jumper socket are connected together. Thus, terminal A of the battery connects directly to the V_{CC} line in the radio. Terminals 2 and 4 of the jumper socket are also connected together, so that the common negative lead of the radio connects to the car chassis, and thus to the negative terminal of the battery.

For positive ground systems, the jumper is inserted so it connects terminal 1 of the jumper socket to terminal 2, and terminal 3 to terminal 4. This connects the negative terminal of the battery to the common negative lead of the receiver, and the positive terminal of the battery (chassis ground) to the $+V_{CC}$ line. Thus, by proper use of the jumper, the radio may be used with either positive or negative ground systems.

A TYPICAL AUTO RADIO

Figure 4 shows the schematic diagram of a typical AM automobile radio. This radio employs six transistors and three diodes. For improved avc action, a voltage doubler is used to rectify a portion of the output of the i-f amplifier. The avc voltage is used to control the base voltage of the r-f amplifier and the i-f amplifier.

The radio is tuned by simultaneously moving the slugs in L_2, L_3 and L_4 which are mechanically connected to the main tuning dial. L_2 together with C_1 is tuned to resonate at the frequency of the incoming signal and couples this signal to the base of Q_1, the r-f amplifier. L_3 together with C_5 and C_6 in the collector circuit of Q_1 tunes to the same frequency. Note that this is not a simple parallel tuned circuit. It is a pi-network and serves as a low-pass filter to reduce image problems by discriminating against frequencies above the oscillator frequency. It also provides impedance matching between the low input impedance of the mixer stage and the much higher impedance in the collector circuit of the r-f stage.

The r-f signal is applied through C_7 to the base of the converter stage, Q_2, which also serves as the local oscillator. The oscillator frequency is above the incoming signal and is controlled by the combination of L_4, C_8 and C_9. The difference frequency produced by beating the r-f signal and the oscillator signal is 262 kHz, and the collector circuit of Q_2 is tuned to this frequency by the primary of L_5, the first i-f transformer.

Q_3 is an i-f amplifier with both base and collector circuits tuned to 262 kHz. A portion of the signal on the collector is fed to avc diodes D_1 and D_2, via C_{15}. D_1 and D_2 are connected to form a voltage doubler similar to those used in power supply circuits. The avc voltage opposes the forward bias supplied by voltage dividers to the bases of Q_1 and Q_3. This voltage is used to control the gain of Q_1 and Q_3.

The i-f signal is detected by D_3, and the audio portion of the signal is developed across the volume control, R_{15}. C_{19}, C_{20} and R_{14} serve to filter out the remaining r-f component of the signal.

The audio signal is coupled to Q_4 by C_{21}. The emitter resistance of this stage, produced by R_{18}, is an internal adjustment which controls the bias throughout the direct-coupled audio amplifier. Changing the setting of this resistor will alter the current through Q_4, thus changing the voltage drop across R_{19}. This, in turn, alters the base voltage on Q_5, which alters the current through this stage and therefore the voltage across R_{21}. This results in a change of base voltage on the power output transistor, Q_6. The interaction between stages in such a direct-coupled amplifier is considerably greater than it would be if coupling capacitors were used to couple stages.

This receiver employs a PNP transistor in the output stage rather than the NPN transistors used throughout the remainder of the circuit. A PNP was chosen because of the low cost of PNP germanium output transistors. This configuration results in the application of a positive supply voltage to the emitter and base of Q_6 and return of the collector to ground through T_1. R_{22}

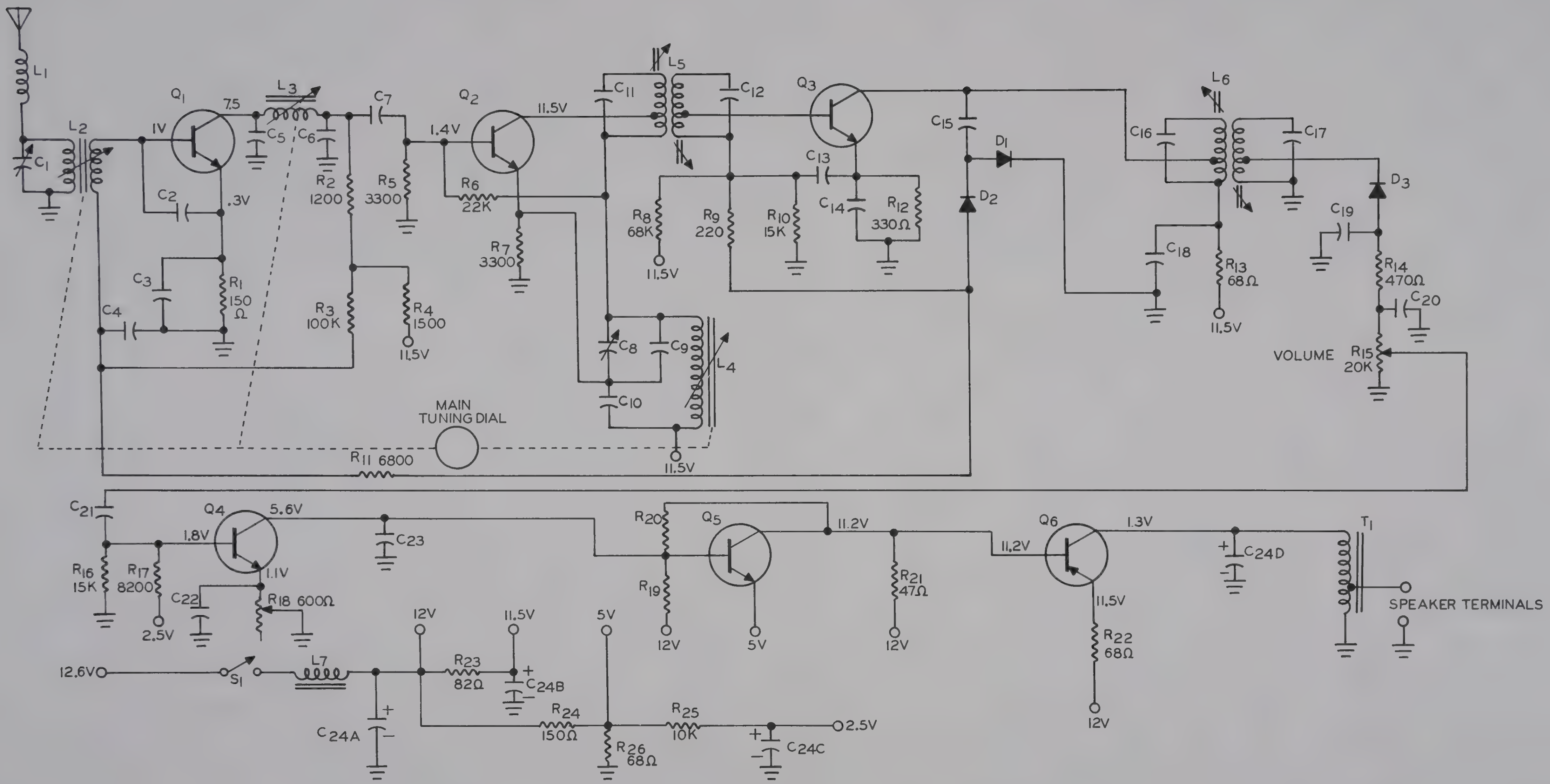

L1
L2
C1
Q1
1V
7.5
.3V
C2
C3
C4
R1 150 Ω
L3
C5
C6
C7
R2 1200
R3 100K
R4 1500
11.5V
R5 3300
Q2
1.4V
11.5V
R6 22K
R7 3300
L5
C11
C12
C8
C9
C10
L4
MAIN TUNING DIAL
11.5V
R11 6800
R8 68K
11.5V
R9 220
R10 15K
Q3
C13
C14
R12 330Ω
C15
D1
D2
L6
C16
C17
C18
R13 68Ω
11.5V
D3
C19
R14 470Ω
C20
VOLUME
R15 20K
C21
Q4
5.6V
1.8V
1.1V
R16 15K
R17 8200
2.5V
C22
R18 600Ω
C23
R20
Q5
R19
12V
5V
11.2V
R21 47Ω
12V
Q6
11.2V
1.3V
11.5V
R22 68Ω
12V
C24D
T1
SPEAKER TERMINALS
12.6V
S1
L7
12V
11.5V
5V
R23 82Ω
C24B
C24A
R24 150Ω
R26 68Ω
R25 10K
C24C
2.5V

Figure 4

in the emitter circuit is a fusible resistor which gives protection for the transistor against excessive current in this stage. This fusible resistor opens up if the current through the transistor reaches approximately twice its normal value. A 10-ohm speaker is used, and the tap on T_1 accomplishes the necessary impedance matching between the speaker and the collector of the output stage.

Power is provided by the car battery and filtered by L_7 and C_{24}. The resistors R_{23} to R_{26} form a voltage divider which delivers the proper potentials for the various stages. This radio is arranged for a negative ground on the car's battery. The 2.5-volt tap on the voltage divider supplies base voltage for Q_4. The 5-volt tap goes to the emitter of Q_5, and the remainder of the positive voltage points indicated in the diagram are connected to the 12-volt taps or the 11.5-volt taps. The receiver draws approximately 650 mA from the 12.6-volt battery.

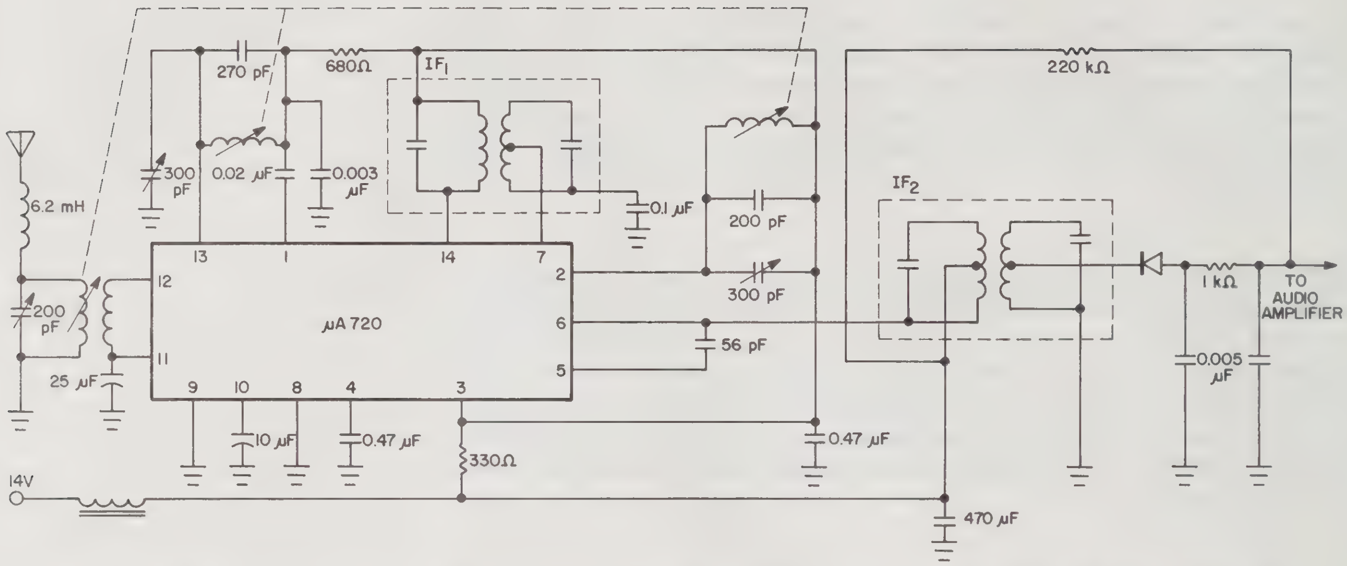
To service this radio on your bench, you would need a well regulated 12.6-volt power supply. It must be capable of handling not only the steady load current but also of handling the surge current required to charge the filter capacitors. You would also need an external speaker equipped either with the proper connector or clipleads, and some form of antenna for checking the response to broadcast signals.

If the radio is reported to be inoperative, we begin with a resistance check at the power input connector before applying power to the circuit. The resistance here should be slightly over 20 ohms, consisting of the small resistance of L_7 plus the equivalent resistance of the voltage divider resistors and the circuits connected across them. A short in C_{24A} will reduce this considerably, and if not checked before turning on power, might damage your bench supply.

Circuit Variations

Although Figure 4 is typical of many automobile radio circuits, variations are common. The audio output circuit may use two output transistors, or an integrated circuit, or a combination of transistors and an IC. The purpose of the audio amplifier remains the same throughout. These variations are similar to those discussed in another lesson and will not be covered here.

Integrated circuits are also coming into common usage in other sections of the automobile radio. Figure 5 illustrates a one IC auto radio that lacks only an audio amplifier. With the addition of one audio amplifier IC, the circuit would represent a complete receiver, using a minimum of components.



THE FAIRCHILD µA720 CONTAINS THE R-F AMPLIFIER, CONVERTER, OSCILLATOR, AGC DETECTOR, VOLTAGE REGULATOR AND I-F AMPLIFIER

Courtesy of Fairchild

Figure 5

Audio Troubles

If power can be safely applied, you can rely on techniques similar to those already examined for home radios. For example, introducing an audio signal across the volume control should tell you whether you are dealing with an audio or r-f trouble. If the difficulty is in the audio section, move the signal source toward the speaker one stage at a time until you locate the defective stage.

Because the audio stages in this audio radio are direct coupled, there is a strong possibility that trouble in one stage may also affect voltage readings in the next. This makes the stage-by-stage process somewhat less revealing than in the circuits examined previously, but it is still the correct procedure.

Let us again refer to Figure 4 and take a look at the effects of the interaction between stages in direct-coupled amplifiers to see what is to be expected when various troubles develop in such circuits. As a start, let's assume that C_{24D} is shorted. Because this is an electrolytic capacitor, this problem could easily occur. What effects might be expected from this malfunction?

To begin with there would be no audio output because there is a direct short across T_1. Another obvious effect is that the collector voltage on Q_6 would be zero instead of the expected 1.3 volts. However, collector current would still be in Q_6. In fact, it would tend to increase because of the increase in voltage between emitter and collector. Any increase in this current will increase the voltage across R_{22}, and thus reduce the positive potential on the emitter. This tends to reduce the current, so it opposes any increase in current. The net result is that both emitter and base voltages would remain very near their original values and no effect on the preceding stages would be noted.

Now, instead of C_{24D} let us assume that a short develops in C_{22}, the emitter bypass capacitor in the first audio stage, Q_4. The effect this time will be more widespread. With C_{22} shorted, the emitter of Q_4 would go to zero volts. Q_4 would therefore conduct heavily because the voltage between base and emitter has increased. This results in the collector voltage decreasing because the increased current through R_{19} causes an increase in the voltage drop at this point.

Notice that the collector of Q_4 is connected directly to the base of Q_5. Thus, any change in Q_4 collector voltage results in a corresponding change in the Q_5 base voltage.

Assume that this voltage reduces to less than the Q_5 emitter voltage. It will, in fact, fall much lower than this. Because the base of Q_5 is then negative with respect to its emitter, this transistor is cut off. As a result, its collector voltage rises toward the 12-volt level because there is a decrease in current through R_{21}. The base voltage on Q_6 also rises because it is directly connected to the collector of Q_5. As the base voltage rises, the current through Q_6 decreases, the emitter voltage increases, and the collector voltage decreases. All of this is a direct result of the variation in emitter voltage on Q_4.

Now let's see how insertion of a signal would work in this radio with C_{22} shorted. If you feed an audio signal to the volume control, you will hear nothing because Q_5 is cut off. The same will be true if you feed the signal into the base of Q_5. You might get an output if you feed an audio signal to the base of Q_6, but it will be badly distorted. The procedure is then to measure the voltage at the terminals of Q_6. With C_{22} shorted, you would read almost zero voltage at the collector and 12 volts on both the base and emitter.

The lack of collector voltage might lead you to believe that T_1 or C_{24D} is shorted, but neither of these would lead to high base voltage. The only way this base voltage can approach 12 volts is if there is a base-to-emitter short in Q_6 or improper current through R_{21}. You can check for the short with an ohmmeter, but because you are measuring voltages you would probably move back to Q_5 and see if there is any reason there for low current through

R_{21}. The base voltage on this stage is less than the emitter voltage. Because this is reverse bias, the trouble is in the biasing of this stage rather than in the final amplifier.

The abnormally low base voltage on Q_5 must be caused by excessive current through R_{19}, and this would seem to indicate the trouble is in the Q_4 stage. So you measure its voltage and discover zero volts on the emitter. The other voltages may also be improper, but we know that if there is current through the transistor, the emitter should not be zero no matter what is wrong elsewhere. An ohmmeter would then show the shorted condition. Disconnecting the capacitor would restore near normal operation, and when the capacitor is replaced, the circuit would operate normally.

As a further example of the complication that can arise in direct-coupled amplifiers, let us consider what happens when an open circuit develops in one of the audio stages. Assume that the lead connecting R_{19} and R_{20} to the collector of Q_4 is broken.

With the lead from R_{19} and R_{20} to the Q_4 collector open, the collector voltage drops and the emitter voltage falls to a very low value. The base voltage will also fall in an attempt to maintain the same voltage between base and emitter. The base voltage of Q_5 will rise sharply because Q_4 is no longer drawing any current through R_{19}. This increased base voltage causes an increase in Q_5 collector current. The resulting increase in Q_5 collector current through R_{21} tends to lower the collector voltage. However, the value of R_{21} is so low that a great increase in current would be required to change this voltage greatly. In any instance, it does go down, which lowers the base voltage on Q_6 and increases the collector current through Q_6. This, in turn, raises the Q_6 collector voltage.

If you insert an audio signal at the volume control you will get no output. However, an audio signal applied to the base of Q_5 will produce a normal or slightly greater-than-normal output. The conclusion would be that Q_4 is the defective stage.

I-F and R-F Troubles

Troubles in the i-f or r-f portion of this receiver would be handled in a very similar manner to that discussed for other transistorized receivers.

Remember, the i-f frequency in the automobile radio is often 262 kHz rather than 455 kHz as used in most home AM receivers.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

INSTALLING AND REMOVING AUTO RADIOS

BENCH POWER FOR AUTO RADIOS

AM AUTOMOBILE RADIOS

POSITIVE AND NEGATIVE GROUND SYSTEMS

A TYPICAL AUTO RADIO

CIRCUIT VARIATIONS

AUDIO TROUBLES

1. What external connections must be disconnected when removing an auto radio for service on the bench?

2. If an auto radio is mounted through the dashboard, what are the normal steps in removing the radio?

3. What is the usual cause of "motorboating" when an auto radio is being serviced in the repair shop?

4. In the power supply of Figure 2, what change occurs in the metering circuits when the range switch is changed from 12 volts to 6 volts?

5. When the power supply shown in Figure 2 is switched from 6 volts to 12 volts, what change is made in the rectifier system?

6. Permeability tuning is frequently used in auto radios to tune the r-f stage, the local oscillator and the mixer. True or False?

7. Most new auto radios use 455 kHz as the i-f. True or False?

8. What would be the result of connecting the jumper plug incorrectly in the circuit of Figure 3?

9. When the radio of Figure 4 is tuned to a station at 1600 kHz, specify the frequency to which each of these coils is tuned: (a) L_2, (b) L_3, (c) L_4, (d) L_5.

10. Does the avc voltage doubler in the receiver shown in Figure 4 produce a negative- or a positive-going voltage when the signal strength of the received signal increases?

11. In Figure 4, reducing the emitter voltage on Q_4 will (a) increase the collector voltage of Q_6, (b) decrease the collector voltage of Q_6.

12. Shorting C_{24D} in Figure 4 will cause the current through T_1 to increase. True or False?

13. In Figure 4, why does an increase in the Q_4 collector current reduce the Q_5 collector current?

14. List at least three voltages which would be abnormal if C_{23} were shorted to ground in the circuit of Figure 4.

15. Assume that R_{22} (emitter of Q_6) shown in Figure 4 were open; explain the steps which would be used to find this trouble.

If the audio portion of the receiver works correctly all the way from the volume control to the speaker, feed in a modulated 262-kHz signal at the base of Q_2. This will check L_5, L_6, Q_3 and the detector. AVC indication can be measured at the base of Q_1, or an output meter can be connected across the voice coil.

If no i-f signal passes through the receiver, the troubleshooting can be confined to the detector, Q_2, Q_3 and i-f transformers L_5 and L_6. If the trouble is in L_6 or detector D_3, the avc voltage may or may not vary with the signal, but there will be no audio output. If the trouble is in L_5 or Q_3, the avc voltage will not rise when the signal is inserted. If the modulated i-f signal can be heard from L_5 onward but no avc voltage is developed, the trouble is in the avc line.

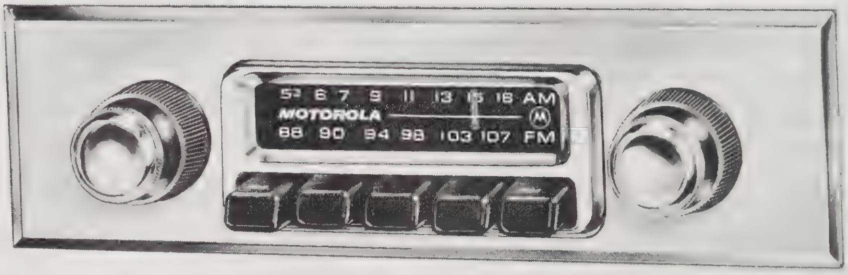
Note that both i-f transformers contain two slugs. The primary of the transformer is generally tuned from the top of the can and the secondary from the bottom. By using the proper alignment tool, some transformers permit both i-f cores to be tuned from one side.

To check the local oscillator, apply a signal near the center of the band and tune the receiver to this frequency. You should hear the signal if the oscillator is working. If the trouble is in the oscillator section, no stations will be received even though the injected i-f signal may be heard. Notice that if oscillator coil L_4 were open, Q_2 would not work at the i-f frequency either because no voltages would be present on this transistor. If the trouble were something like an open on the circuit board between the junction of C_8 and C_{10} and the emitter, the oscillator would not operate but the transistor would still amplify 262-kHz signals.

Trouble in Q_1 (the r-f amplifier stage) would prevent signals from reaching the converter. In this situation feeding signals into the base of Q_2 would produce an output, but feeding the same signal into the antenna would not. This might also result if L_1, L_2 or L_3 were open, or if one of the capacitors in this section were either open or shorted.

Once the defective stage has been pinpointed by this method of feeding in the appropriate signal to each stage, voltage or resistance measurements can be used to locate the defective component. The application of logic to any of these circuits will quickly tell you which parts must be checked once the defective stage has been isolated for detailed checking.

To illustrate the application of logic to the troubleshooting process, assume that the radio works when signals are applied to Q_2, but not when they are



This AM-FM auto radio employs an Insulated Gate Field Effect Transistor (IGFET) in the r-f amplifier stage as well as integrated circuits in the FM i-f strip.
Courtesy Motorola Inc.

applied to the antenna. You know at once that your measurements should be concentrated in the Q_1 stage. If the collector voltage in this stage is zero, you know there is trouble between the collector and the 11.5-volt supply point. You would then move to the junction of R_2, R_3 and R_4 and check the voltage. If it is present here, check on the side of R_2 that is connected to the collector of Q_1. If there is no voltage here, the possibilities are reduced to an open connection between R_2 and R_4 or a short between ground and the end of R_2 that is nearest to the Q_1 collector. An ohmmeter test will quickly tell you which defect exists. If it turns out to be a short, you must determine if it is in C_5, C_6, the transistor, or an L_3 short to its case. This you can do by disconnecting each in turn and checking with the ohmmeter.

Conversely, if voltage is present beyond R_2 but not at the transistor, the odds are that L_3 is open. Again, the ohmmeter will verify this. Similar step-by-step procedures will lead you to a defective connection or part anywhere in the r-f or i-f section.

Alignment of auto receivers follows the same general procedure as followed when aligning conventional broadcast receivers. The only difference is the lower i-f frequency found in most auto receivers. The avc line or the speaker can be used for the output indication. Always start with the last i-f stage and work towards the front end. It may be necessary to disable the local oscillator during i-f alignment to prevent interference. Follow the recommended procedure set up by the manufacturer. With the permeability tuning employed in auto receivers, you may have to adjust both the position of the slug as well as a trimmer connected across the coil. The trimmers are always adjusted at the high end of the band.

Unless some major component in the i-f or r-f section is changed, a complete alignment should not be necessary. However, you might want to touch up the alignment if performance indicates that the alignment is off. This can be caused by slight changes in component values as they age. The antenna trimmer, C_1 in the circuit of Figure 4, should be touched up only with the receiver in the automobile. C_1 is usually accessible, so it can be adjusted with the receiver mounted under the dashboard. This adjustment is generally made at the high end of the band. Pick out a weak station and adjust C_1 for the best performance.

FM AUTOMOBILE RADIOS

In recent years there has been a considerable increase in the number of automobile FM receivers. In metropolitan areas, coverage by FM broadcast stations is quite good and many such stations have antennas which provide both horizontal and vertical polarization in order to better serve auto radios.

One of the inherent advantages of FM transmission is improved noise suppression in the receiver. Pulse-type noise such as that produced by auto ignition systems is largely eliminated by FM detector circuits.

Figure 6 is a schematic diagram of a typical FM automobile radio. Beyond the detector there is no essential difference between an AM receiver and an FM receiver. Once the signal has been converted to audio, all circuits work in the same general manner. Frequently, however, a better quality audio amplifier is included in the FM receiver.

In the receiver of Figure 6, the audio section uses a push-pull output stage with transformer coupling both between the driver and the power amplifier and between the speakers and the collectors of the output transistors.

Note that the voltage applied from the battery is arranged so that the common ground within the radio is the most positive point in the circuit, and any points to which voltages are applied are all negative with respect to ground. PNP transistors are used in the audio stages and negative voltage is applied to the collectors of these transistors with the emitters returned to ground through resistors. The collectors of the NPN transistors used in the r-f and i-f stages have their collectors grounded. Note also that wherever electrolytic capacitors are used for filtering or bypass functions, the positive side of the capacitor is tied to ground.

The procedure for isolating trouble in the audio section of this receiver is identical to that previously described for AM receivers. An audio signal is injected first at the volume control. If there is no output from the speaker, you move the input signal one stage toward the speaker. When you reach a point where normal operation occurs, assume the previous stage to be the defective one, and begin your voltage measurements in that stage. If you find any abnormal voltages, turn off the receiver and use the ohmmeter to find the defective part or open circuit on the printed circuit board.

The greatest difference between FM and AM receivers is in the detector circuits. The FM detector, usually a ratio detector or discriminator, responds to frequency variations, whereas the AM detector responds to amplitude variations.

In examining the r-f portion of this receiver, notice that the signal from the antenna is applied to the emitter rather than to the base of the r-f transistor. The output of this stage is coupled to the emitter of the converter stage. Thus, the r-f amplifier and converter stages are operated in the common base configurations. Common base operation is desirable at high frequencies because it tends to reduce the effects of the internal capacitance of the transistor, and improves its high-frequency response. An i-f trap, made up of L_3 and C_{18}, serves to prevent radiation of the i-f signal.

The receiver tunes from 88 MHz to 108 MHz to cover the FM broadcast band. C_{49A} resonates L_2 to the frequency of the incoming station and C_{49B} controls the local oscillator frequency in conjunction with L_4. The oscillator frequency is stabilized by an automatic frequency control circuit which includes variable capacitance diode D_2.

D_2, a varactor diode, acts as a variable capacitor whose capacitance is dependent on the voltage across it. A varactor diode is a special type of diode that has the ability to simulate a capacitor. As reverse-bias voltage (within a specified range) increases, capacitance decreases.

In Figure 6, C_{21}, D_2 and C_{22}, all in series, are connected in parallel with the frequency controlling capacitor C_{49B}. Because D_2 has a very small capacitance compared to those in series with it, it has the greatest effect on the total capacitance in this branch of the parallel circuit. This total capacitance adds to that of C_{49B}. Any variation in the capacitance of D_2 will slightly shift the oscillator frequency.

One of the properties of a ratio detector is that when the applied signal is exactly at the center frequency to which it is tuned, the detector has zero dc output voltage, but when the incoming signal is not at the center frequency, a dc voltage is developed at the detector output. The polarity of this voltage depends on which way the incoming signal is off center. D_2 is connected to the output of the ratio detector through R_{17}. If the oscillator drifts off frequency, a voltage of the proper polarity is applied to D_2 to alter its capacitance and pull the oscillator back to its original frequency.

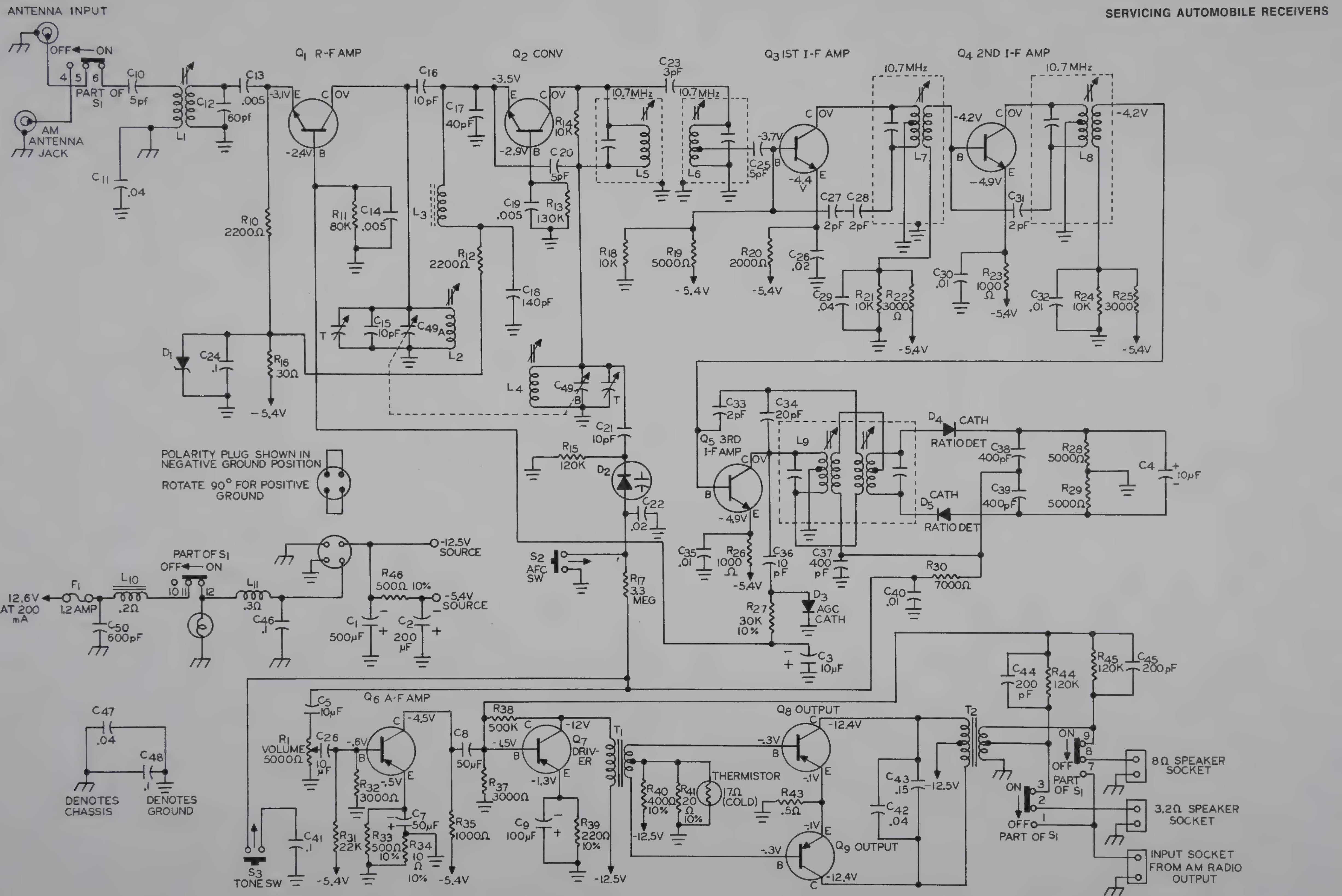

ANTENNA INPUT
OFF ← ON
PART OF S1
AM ANTENNA JACK
C10 5pf
L1
C12
C13 .005
60pf
C11 .04
Q1 R-F AMP
-3.1V E
C OV
-2.4V B
R10 2200Ω
R11 80K
C14 .005
C16 10pF
C17 40pF
L3
R12 2200Ω
C15 10pF
C49A
L2
T
D1
C24 .1
R16 30Ω
-5.4V
Q2 CONV
-3.5V
E
C OV
-2.9V B
R14 10K
C20 5pF
C19 .005
R13 130K
C18 140pF
L4
C49B
T
C21 10pF
R15 120K
D2
C22 .02
C23 3pF
10.7MHz
L5
L6
C25 5pF
Q3 1ST I-F AMP
C OV
-3.7V
B
-4.4V
E
C27 2pF
C28 2pF
L7
R18 10K
R19 5000Ω
R20 2000Ω
C26 .02
-5.4V
C29 .04
R21 10K
R22 3000Ω
Q4 2ND I-F AMP
-4.2V
C OV
B
-4.9V
E
C31 2pF
L8
C30 .01
R23 1000Ω
C32 .01
R24 10K
R25 3000Ω
POLARITY PLUG SHOWN IN NEGATIVE GROUND POSITION
ROTATE 90° FOR POSITIVE GROUND
Q5 3RD I-F AMP
C33 2pF
C34 20pF
L9
C OV
B
-4.9V
E
C35 .01
R26 1000Ω
C36 10 pF
C37 400 pF
D4 CATH
RATIO DET
C38 400pF
C39 400pF
D5 CATH
RATIO DET
R28 5000Ω
R29 5000Ω
C4 10μF
R30 7000Ω
C40 .01
D3 AGC CATH
R27 30K 10%
C3 10μF
S2 AFC SW
R17 3.3 MEG
-12.5V SOURCE
-5.4V SOURCE
R46 500Ω 10%
PART OF S1
OFF ← ON
10 11 12
F1 1.2 AMP
L10 .2Ω
L11 .3Ω
12.6V AT 200 mA
C50 600pF
C46 .1
C1 500μF
C2 200 μF
C47 .04
C48 .1
DENOTES CHASSIS
DENOTES GROUND
Q6 A-F AMP
C5 10μF
R1 VOLUME 5000Ω
C26 10 μF
-.6V
B
C -4.5V
-.5V E
R32 3000Ω
C7 50μF
R31 22K
R33 500Ω 10%
R34 10 Ω 10%
R35 1000Ω
S3 TONE SW
C41 .1
C8 50μF
R38 500K
-1.5V
B
C -12V
Q7 DRIVER
-1.3V E
R37 3000Ω
C9 100μF
R39 220Ω 10%
-12.5V
T1
R40 4000Ω 10%
R41 20 Ω 10%
THERMISTOR 17Ω (COLD)
R43 .5Ω
Q8 OUTPUT
-.3V B
C -12.4V
-.1V E
Q9 OUTPUT
-.3V B
-.1V E
C -12.4V
C43 .15
C42 .04
T2
C44 200 pF
R44 120K
R45 120K
C45 200 pF
ON OFF 9 8 7
PART OF S1
8Ω SPEAKER SOCKET
3.2Ω SPEAKER SOCKET
ON 3 2 1 OFF
PART OF S1
INPUT SOCKET FROM AM RADIO OUTPUT

Figure 6

This receiver uses the conventional FM intermediate frequency of 10.7 MHz. The collector of Q_2 is tuned to this frequency by L_5. Notice that L_5 and L_6 are mounted in two separate cans, so that there is no inductive coupling between them. The two coils are capacitively coupled rather than transformer coupled to increase the bandwidth at this point.

Q_3 and Q_4 are i-f amplifiers using NPN transistors. Because of the negative polarity of the supply voltage, these stages, along with Q_1 and Q_2, have their collectors returned to ground through a low impedance, resulting in zero dc voltage on the collectors of all four stages. The negative supply voltage is applied to the emitter circuits of these transistors.

While Q_5 appears to be a conventional i-f amplifier, and does provide amplification of small signal, the size of the signal when it reaches this stage is sufficient to drive this amplifier from saturation to cutoff on any strong signal. This is done so that the stage acts as a limiter and the output to the detector is of constant amplitude. Thus, no variations in amplitude such as those caused by noise reach the detector.

The collector of Q_5 supplies a signal not only to the ratio detector but also through C_{36} to the agc diode, D_3. On strong signals where Q_5 is acting as a limiter, the level of this agc voltage is constant. But when a weaker signal is tuned in, the agc voltage reduces, and less voltage is applied to the base of Q_1, thus increasing its gain.

The heart of any FM receiver is the detector. The receiver of Figure 6 uses a ratio detector employing two diodes, D_4 and D_5. The i-f signal is developed across the primary of specially wound transformer L_9, and induces a voltage in the untuned tertiary winding. The tertiary winding couples a signal to the center of the L_9 secondary that is in phase with the top of the L_9 primary. This signal is also 90 degrees out-of-phase with either the top or bottom of the L_9 secondary. In addition, the signal from the collector of Q_5 is capacitively coupled to a second primary which is inductively coupled to the center tapped secondary of L_9. The audio output appears between the junction of C_{38} and C_{39} and the junction of R_{28} and R_{29} (ground).

When the incoming signal is at the center of the bandpass of this transformer, stabilizing capacitor C_4 charges to the average value of the signal. The symmetrical voltage divider consisting of C_{38} and C_{39}, and R_{28} and R_{29} makes the output voltage zero at this time.

When frequency modulation causes the carrier to deviate from this center frequency, conduction of one diode increases, while conduction of the other decreases. The ratio of the voltages across C_{38} and C_{39} changes proportionally to the instantaneous carrier deviation. Because the rate of change is controlled by the frequency of the modulating signal, and the amount of change is controlled by the amplitude of the modulating signal, the original audio signal is recovered and is applied through R_{30} and C_5 to the volume control, R_1.

Having examined the basic circuitry of this receiver, let's consider the problems involved in troubleshooting the unit when service is required in the r-f or i-f section. When the trouble is in the r-f, i-f or detector sections of the receiver, you will be dealing with slightly different servicing problems than those found in AM radios. One factor that will alter your procedure is that you are dealing with much higher frequencies in an FM receiver. For this reason, replacement parts in the r-f or i-f section must be positioned with care. Remember that at these frequencies lead dress and lead length may seriously affect performance.

Another difference in your servicing approach is caused by the difference in the detector circuit. If you are using a normal amplitude-modulated r-f generator, you cannot obtain audio output merely by modulating the incoming signal because the ratio detector is not affected by amplitude modulation. Instead, you must use an unmodulated r-f signal at the FM i-f, and check the voltage across C_4 as an output indication. To give reliable results, the input signal must be small enough to keep Q_5 below the saturation level; otherwise, the voltage across C_4 will remain constant. If the detector is not functioning, the measurement can also be made at the avc line at the junction of R_{27}, C_{36} and D_3.

A failure in the r-f, local oscillator or i-f portions would prevent signals from reaching the detector. Inserting the i-f signal (10.7 MHz) into the base of each of the i-f transistors should enable you to identify a defective i-f stage. If the signal path through a stage is abnormal but voltage readings appear normal, check bypass capacitors as well as coupling capacitors.

Zener diode D_1 serves as voltage regulator for the emitter voltages on the first two transistors. Voltage at the junction of R_{16} and D_1 should be a constant 4.6 volts. Changes in base voltage on either Q_1 or Q_2 should not affect this voltage.

The schematic shown in Figure 7 represents the FM portion of a state-of-the-art AM-FM/STEREO automobile receiver. The multiplex circuitry is not shown, as it is nearly identical to that used in home receivers, and is discussed in another lesson.

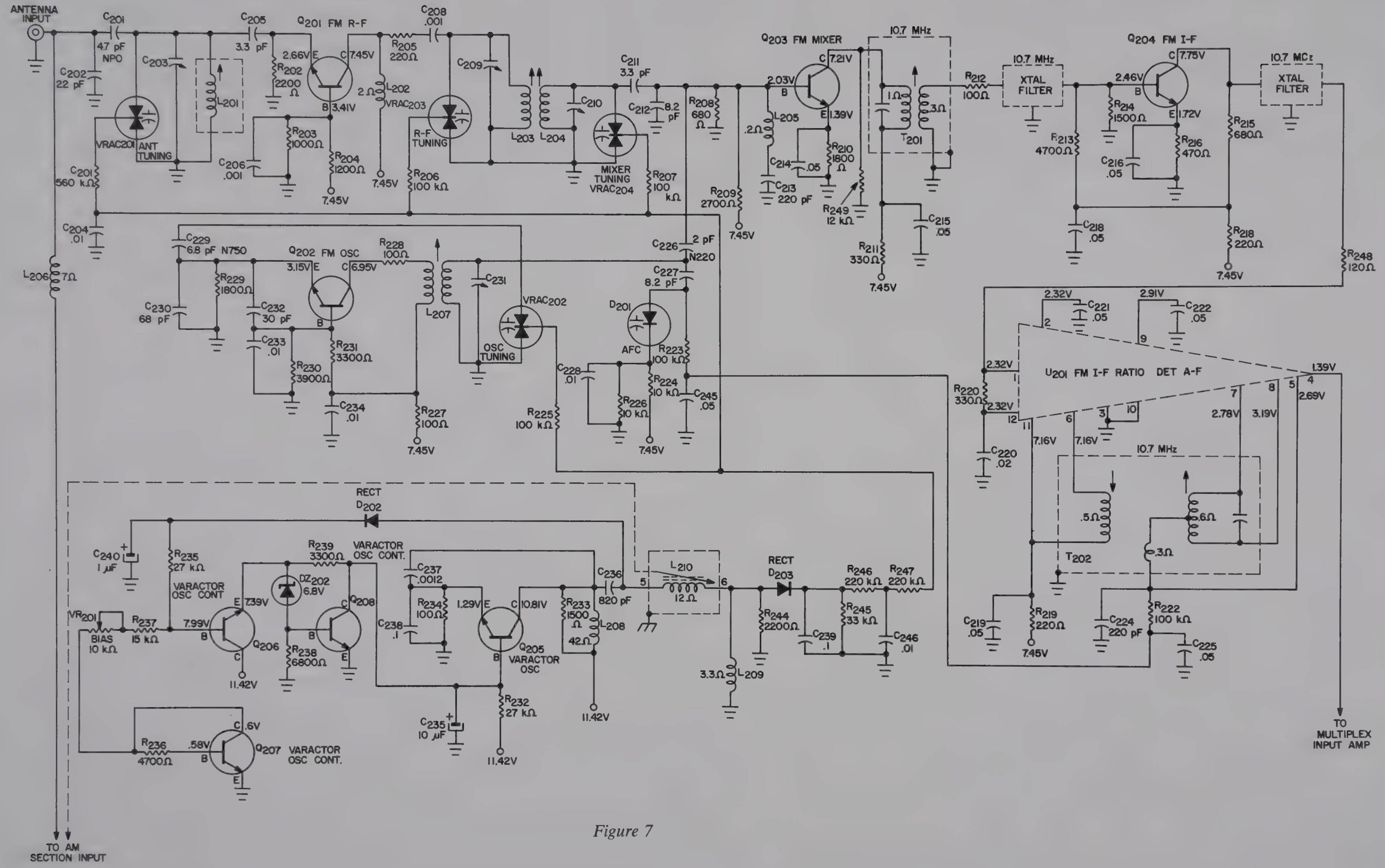

ANTENNA INPUT
C201 47 pF NPO
C202 22 pF
C203
L201
VRAC201 ANT TUNING
C201 560 kΩ
C204 .01
L206 7Ω
C205 3.3 pF
R202 2200 Ω
Q201 FM R-F
2.66V E
C 7.45V
B 3.41V
R203 1000Ω
C206 .001
R204 1200Ω
7.45V
R205 220Ω
C208 .001
L202 2.Ω
VRAC203 R-F TUNING
R206 100 kΩ
C209
L203 L204
C210
C211 3.3 pF
C212 8.2 pF
VRAC204 MIXER TUNING
R207 100 kΩ
R208 680 Ω
R209 2700Ω
Q203 FM MIXER
2.03V B
C 7.21V
E 1.39V
L205 .2Ω
C214 .05
C213 220 pF
R210 1800 Ω
R249 12 kΩ
10.7 MHz
T201 1Ω .3Ω
R211 330Ω
C215 .05
R212 100Ω
10.7 MHz XTAL FILTER
Q204 FM I-F
2.46V B
C 7.75V
E 1.72V
R214 1500Ω
R213 4700Ω
C216 .05
R216 470Ω
C218 .05
R215 680Ω
R218 220Ω
10.7 MCz XTAL FILTER
R248 120Ω
C229 6.8 pF N750
Q202 FM OSC
3.15V E
C 6.95V
R228 100Ω
R229 1800Ω
C230 68 pF
C232 30 pF
C233 .01
R230 3900Ω
R231 3300Ω
C234 .01
L207
C231
VRAC202 OSC TUNING
R227 100Ω
C226 2 pF N220
C227 8.2 pF
D201 AFC
R223 100 kΩ
C228 .01
R226 10 kΩ
R224 10 kΩ
C245 .05
R225 100 kΩ
U201 FM I-F RATIO DET A-F
2.32V
C221 .05
2.91V
C222 .05
R220 330Ω
C220 .02
7.16V
2.78V 3.19V
1.39V
2.69V
10.7 MHz
T202 .5Ω .6Ω .3Ω
C219 .05
R219 220Ω
C224 220 pF
R222 100 kΩ
C225 .05
TO MULTIPLEX INPUT AMP
RECT D202
C240 1 µF
R235 27 kΩ
VARACTOR OSC CONT
VR201 BIAS 10 kΩ
R237 15 kΩ
7.99V B
E 7.39V
Q206
11.42V
R239 3300Ω
VARACTOR OSC CONT.
DZ202 6.8V
Q208
R238 6800Ω
C237 .0012
R234 100Ω
C238 .1
1.29V E
C 10.81V
Q205 VARACTOR OSC
R233 1500 Ω
L208 42Ω
C236 820 pF
L210 12Ω
C235 10 µF
R232 27 kΩ
R236 4700Ω
.58V B
C .6V
Q207 VARACTOR OSC CONT.
RECT D203
R246 220 kΩ
R247 220 kΩ
R244 2200Ω
C239 .1
R245 33 kΩ
C246 .01
L209 3.3Ω
TO AM SECTION INPUT

Figure 7

There are two basic areas of change between the circuits shown in Figures 6 and 7. These are the method of tuning and the method of i-f signal processing.

The FM receiver shown in Figure 6 uses permeability tuning for mechanical stability. The receiver in Figure 7 uses varactor diode tuning. Varactor diodes are also mechanically very stable and allow the designer to eliminate the elaborate mechanics of ganging many variable inductors. All of the varactors, except the afc varactor, are simply controlled by one variable voltage source.

Even though varactor diodes are mechanically stable, they are by design electrically unstable. A small change in supply voltage also means a change in the capacitance of each varactor diode.

In an ac powered receiver, the varactor supply voltage comes from a potentiometer, which controls the output of a dc power supply. The reasonably stable line voltage and the regulation provided by the dc power supply keep drift at a minimum. What few instabilities remain are corrected by the afc circuit.

The supply voltage fed to an automobile receiver varies a great deal more than the line voltage of an ac receiver. As a result, the simple method of providing varactor control voltage in an ac receiver is unsuitable for use in an automobile receiver.

Referring again to Figure 7, the problem of obtaining a stable control voltage is solved by a rather unique power supply. A highly stable oscillator circuit consisting of transistors Q_{205}, Q_{206}, Q_{207} and Q_{208} produces an ac output signal. This signal is applied to an ac voltage divider consisting of L_{210} and L_{209}. L_{210} is permeability tuned and ganged to the receiver's tuning control. As the receiver is tuned, the inductance of L_{210} is varied. This alters the characteristics of the voltage divider and provides an ac output that varies with receiver tuning. This ac signal is rectified by D_{203} and filtered by a network consisting of C_{239}, R_{245}, R_{246} and C_{246}. The resultant stable dc signal is applied to the varactor tuning diodes through individual dropping resistors.

In this circuit, the varactor tuning diodes are dual diodes. That is, they are two varactor diodes in one case, internally connected. The control voltage applied to their common tie point affects each diode equally.

The varactor control is essentially the same for each stage. For purposes of simplicity, we will only examine the operation of mixer tuning. Figure 8A

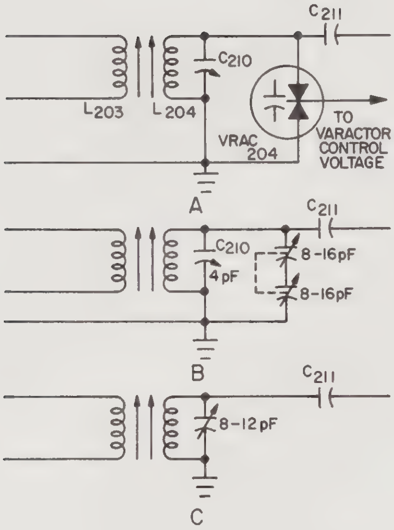


Figure 8

shows the L-C circuit preceding the FM mixer. We will assume that trimmer capacitor C_{210} is fix tuned to 4 pF. The varactor diode has a total range of 4 to 8 pF or 8-16 pF per section.

Figure 8B illustrates the direct equivalent of the circuit shown in 8A. The two 8-16 pF variable capacitors cover the same range of capacitance as $VRAC_{204}$. The only functional difference is that a varactor diode is lower in Q than an air dielectric variable capacitor. Figure 8C is the same circuit, reduced to its simplest equivalent. The tuning range of 8-12 pF is exactly the same as that achieved by placing $VRAC_{204}$ in parallel with C_{210}.

The second major difference between the circuits shown in Figures 6 and 7 is the method i-f signal processing.

The circuit in Figure 6 used several i-f transformers and exclusively discrete i-f components. As shown in Figure 7, the newer i-f circuit is quite different. After the i-f signal is developed, it is applied to T_{201}. T_{201} shapes the i-f signal and couples it into the first crystal filter, through R_{212}.

The crystal filters are used in place of i-f transformers. They require no alignment and provide the wide uniform frequency response needed for good FM stereo. Q_{204} makes up for the losses of the first crystal filter and adds i-f gain. The second crystal filter improves i-f selectivity, while not detracting from the response of the i-f signal.

U_{201} is a linear integrated circuit, containing a high-gain multistage i-f amplifier, limiter, ratio detector stage and an audio preamplifier/driver. This integrated circuit reduces receiver cost and complexity, and delivers more gain than the discrete i-f amplifier shown in Figure 6.

ALIGNMENT OF FM RECEIVERS

Alignment of an FM auto receiver is basically similar to alignment of an AM auto receiver, although the detector requires special attention. In the receiver shown in Figure 6, the wide bandwidth required is a function of the design and not generally an alignment problem. The i-f transformers in this receiver, L_5, L_6, L_7 and L_8, may be aligned by applying a 10.7-MHz signal to the emitter of Q_2. The voltage across C_4 in the ratio detector, or at the C_3 end of R_{27} on the avc line can be used as the indicating device. Each of the i-f transformers should be tuned for maximum output.

To tune transformer L_9 if you are using a standard signal generator rather than a sweep generator, connect the indicating device through an isolation resistor of at least 1 megohm to the junction of C_{38} and C_{39} and tune the primary of L_9 for a maximum reading. Then, tune the secondary of L_9 for a zero reading. It may be necessary to detune the secondary of L_9 to get a reading when the primary is tuned. When the generator is shifted to a slightly higher frequency, a positive voltage will be obtained, and below the center frequency a negative voltage will appear. A meter having a zero voltage center reading is helpful, or an electronic meter can be adjusted to read midscale with no input.

Better overall alignment can be obtained using an FM sweep generator and an oscilloscope. The generator should have a deviation of 400 kHz, a 60-Hz sweep rate and 100-kHz markers which can be set to 10.6, 10.7 and 10.8 MHz. Temporarily disconnect C_4 and connect the oscilloscope to the ungrounded end of R_{29}. Tune all i-f cans including the L_9 primary for maximum output at the center frequency marker. The markers at 10.6 MHz and 10.8 MHz should both be equally spaced down the sides of the response curve as shown in Figure 9. This symmetrical shape of the curve is important in obtaining good audio quality. If one of the markers is higher on the slope of the curve than the other, adjust one or more of the i-f transformers beginning at L_5 to obtain better balance even if some loss of gain at 10.7 MHz occurs.

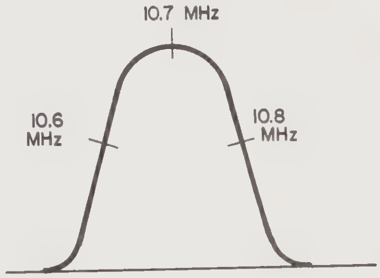


Figure 9

The waveshape shown in Figure 9 is an idealized drawing. It can seldom be obtained in actual practice. The oscilloscope pattern you actually see may vary considerably from this. For example, the oscilloscope may invert it. The pattern may also show a retrace line. There may also be some nonlinearity in your pattern caused by the oscilloscope. Many scopes tend to compress the trace on the right side of the screen at slow sweep rates.

The markers may not resemble those shown in the drawing. Particularly when positioned on the slopes of the curve, the markers may distort the pattern. Keep the amplitude of the marker signal at a low level to minimize this effect.

Once you have learned what patterns to expect from your scope, when the receiver being tested is properly aligned, the distortion caused by the test equipment is not a problem. When first working with alignment by sweep generator you must bear in mind that the patterns, exactly as shown in our figures or accompanying servicing data sheets, are not necessarily obtainable on your oscilloscope.

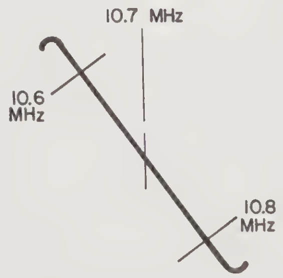


Figure 10

To adjust the discriminator using this sweep generator method, reconnect C_4 and move the scope input to the junction of C_{38} and C_{39} and set the scope sweep to 120 Hz. The figure obtained on the oscilloscope should be like that shown in Figure 10. The secondary of L_9 should be tuned to center the

This sweep generator includes both crystal and tunable marker generators.

Courtesy Eico Electronic Instrument Co., Inc.

10.7-MHz marker on the oscilloscope pattern. The primary of L_9 is then retouched to obtain the best possible linear slope on the curve. The linear portion of the curve should extend out to well beyond the 10.6- and 10.8-MHz markers.

Alignment should only be required when some tuned portion of the r-f or i-f system has been replaced. We want to re-emphasize that lead length and parts replacement are important at these frequencies. Misalignment may result from merely having displaced some components while probing the set in search of the trouble.

CAR TAPE PLAYERS

A recent innovation in the auto radio field is the use of cartridge tape players. These units reproduce stereo music from prerecorded 8-track stereo tapes. Four separate stereo selections are available on the tape, each using two tracks. Any of the four pairs of tracks may be selected by the listener, or the tape player will switch automatically from one to another at the end of each tape cycle. At a speed of $3^3/_4$ inches per second, total playing time for one of the cartridges is about 90 minutes.

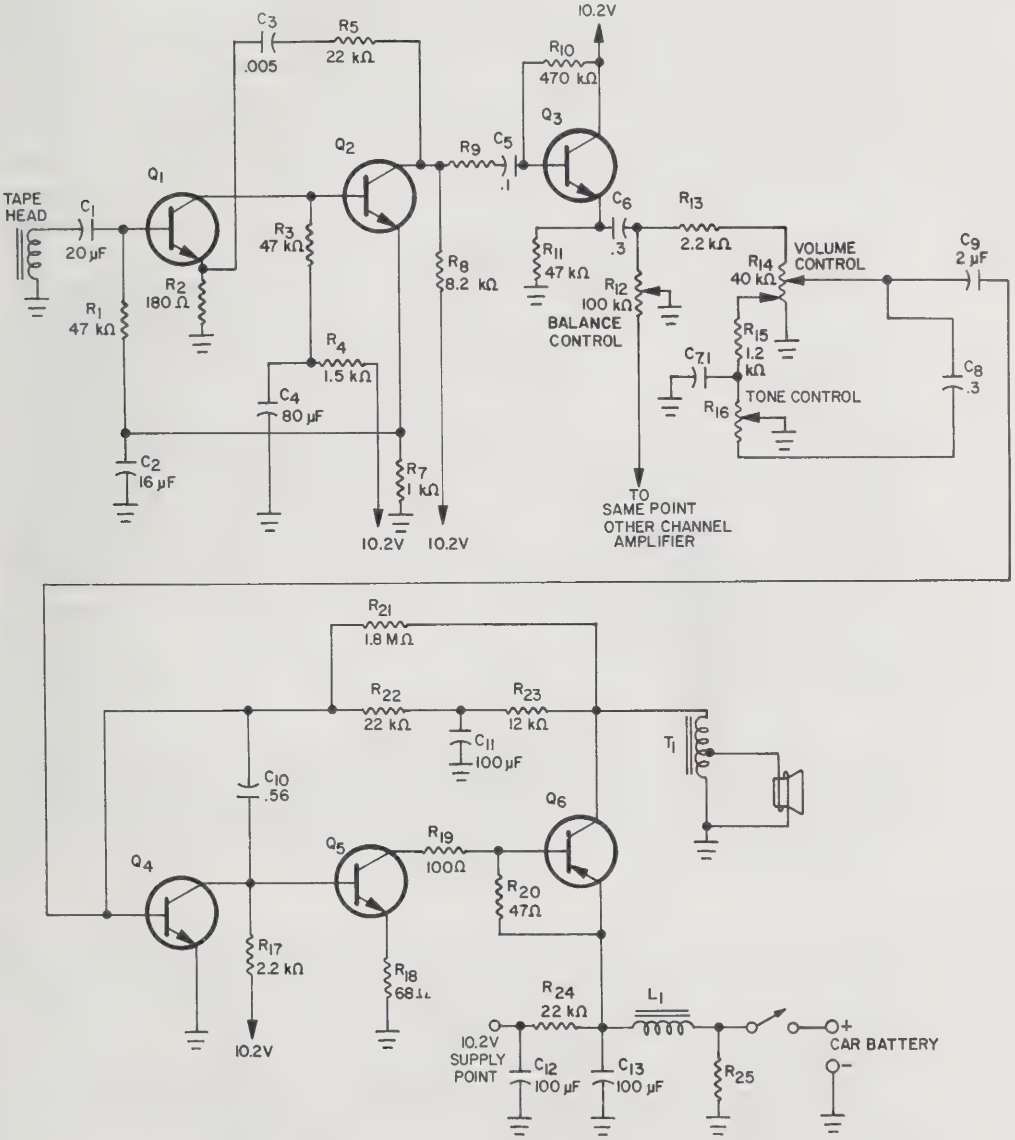


Figure 11

Figure 11 shows a schematic diagram of such a tape player. Only one channel is shown because both the left and right channels are identical. The circuit from the volume control to the speaker is similar to the direct-coupled audio portion of the AM receiver previously discussed. Any troubles occurring here can be analyzed in the same manner previously described. Remember that in direct-coupled amplifiers, troubles in one stage may alter voltages in all stages.

Temperature stability is an important consideration in direct-coupled amplifiers. In this circuit, temperature stability is obtained by using the current through Q_6 to control the bias on Q_4 through the R_{21}, R_{22} and R_{23} network. Any increase in current through Q_6 causes the Q_6 collector voltage to become more positive. In turn, this causes the voltage on the base of Q_4 to become more positive. This NPN transistor then conducts harder, lowering the base voltage on Q_5 and making the voltage on the base of Q_6 more positive. Because Q_6 is a PNP transistor, increased positive base voltage reduces collector current in this stage, thus tending to maintain the original level of conduction.

To explain the operation of the entire circuit, let's begin at the pickup head and trace the signal through to the speaker. The signal prerecorded on the magnetic tape induces a small audio-frequency voltage in the coil of the tape head. This is fed through C_1 to the base of Q_1. Because this is a much smaller audio voltage than you would be dealing with at the output of a radio's detector, it requires additional amplification. This is accomplished by two direct-coupled amplifiers, Q_1 and Q_2. Because the signal level is very small, a low-noise transistor is required in the input stage. This is an important consideration when replacing transistors in low-level audio amplifiers. The frequency response of most tape recordings drops off in the low-frequency region, so a feedback network consisting of C_3 and R_5 is used to boost the low frequencies more than the highs, thus providing a flat frequency response.

The third stage, Q_3, is an emitter follower for impedance matching purposes rather than gain. The output impedance of Q_2 is too high to feed it directly to the volume control and base of Q_4. Taking the signal developed across R_{11} in the emitter of Q_3 gives a much better match.

In troubleshooting this amplifier, remember that it contains two separate direct-coupled portions, separated by the emitter follower stage, Q_3. The volume control is still a good dividing point at which to begin and work forward toward the speaker, if the trouble is still evident. If the signal is normal from there, work backwards towards the tape head. Remember also that Figure 11 shows only half of the unit. There is an identical amplifier for the other channel in the stereo system.

The only portions of the circuit common to both channels are the power supply filter and the balance control. The balance control is used to adjust the two amplifiers' relative volume to achieve the best stereo balance.

Many service problems connected with these tape players are not caused by the amplifiers. Mechanical considerations involved in the tape transport and head alignment can result in unsatisfactory performance.

One important cause of inferior performance is a build-up of iron oxide on the head and the drive capstan. The oxide rubs off of the tapes and slowly accumulates on any surface in contact with the tape. It must be cleaned off occasionally. To do so, use the eraser end of a pencil to close the motor start switch, which is normally closed by the insertion of the tape cartridge. Then with the motor running, clean both the capstan and the tape head with a cotton swab dipped in alcohol or a head cleaner recommended by the manufacturer. Do not use carbon tetrachloride. Wipe dry after cleaning with a dry swab. A cleaning cartridge may also be used for head cleaning. The cleaning cartridge is inserted in the player and allowed to run for a predetermined time. After cleaning, the tape head should be demagnetized. Narrow demagnetizing tools are available and are ideal for use on cartridge players. To use the tool, bring the demagnetizer close to the head, withdraw it slowly, and then shut off its power.

Proper alignment of the tape and the head are very important for good reproduction. Each band of recorded information is only about .02 inch wide and the guard band between adjacent tracks on the tape is only .01 inch wide. It is obvious that the positioning of the head is critical. Special test tapes are available to assist in adjustment of the head to the proper position.

Two adjustments are required to properly position a head: a height adjustment to move the head up or down so that it is exactly tracking with the prerecorded tracks, and an azimuth adjustment to ensure that the head contacts the tape at the proper angle. Misadjustment of the height control will cause crosstalk between channels, and misadjustment of the azimuth causes poor high-frequency response.

Both adjustments are generally made with an allen wrench. The setscrews are usually located between the flywheel and the motor within the V formed by the drive belt. There are any number of test tapes available. Refer to the

This eight-track stereo tape player has a built-in multiplex adaptor which permits stereo FM operation when used with a conventional FM receiver.

Courtesy Motorola, Inc.

alignment procedure supplied with the tape. The following is typical of such instructions: "Using a test tape, set the unit to play track 2 and adjust the screw for minimum output on the left channel. Next, adjust the azimuth screw, using track 6 of the test tape. This contains a continuous 8-kHz note. The screw should be set for maximum output on the right channel." The reason for the track 2 adjustment is that the material on this track of the test tape is recorded on the guard bands between Channels 1 and 2 and 2 and 3, rather than on track 2. You are making sure there is no pickup from the guard bands.

Two additional adjustments are associated with the head, but usually require no adjustment unless the head is replaced. One of these adjusts head tension and the other positions the entire head. The positioning adjustment is critical to within .005″ and should never be tampered with unless accurate gauges are available to reset it.

The tape drive motor speed is generally 3000 rpm, which is reduced by the fly wheel to the proper speed of $3^3/_4$ inches per second. The motor contains a mechanical governor for speed regulation. Field repair of the motor is not recommended. A defective motor should be replaced.

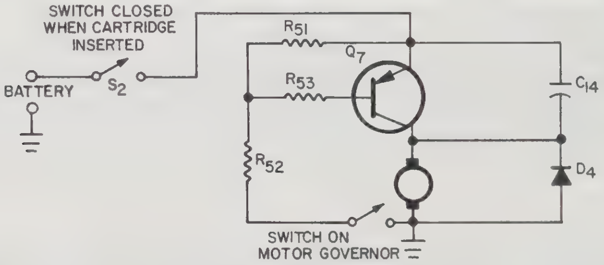


Figure 12

The motor voltage is supplied by a transistor regulator circuit such as the one shown in Figure 12. If the motor speed is too slow, this circuit might be suspected. The voltage at the collector of this transistor should hold at approximately 7 volts. When the motor speed exceeds 3000 rpm, the governor contacts open, disconnecting R_{52} from ground. This raises the base of the transistor to the same voltage applied to the emitter, cutting off the transistor. No current can be drawn by the motor until its speed falls below 3000 rpm, thus grounding R_{52}, allowing the transistor to again conduct. This off and on switching occurs more than 100 times per second. Diode D_4 is included to prevent transient spikes across the motor from damaging the transistor. Motor switch S_2 between the battery and the regulator is activated whenever a tape cartridge is pushed into the tape player slot.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

A TYPICAL AUTO RADIO

I-F AND R-F TROUBLES

FM AUTOMOBILE RADIOS

ALIGNMENT OF FM RECEIVERS

CAR TAPE PLAYERS

16. Assume that an open connection exists between the primary of L_6 and R_{13} in the receiver shown in Figure 4. Will the avc voltage at the base of Q_1 vary normally when a 262-kHz i-f frequency is introduced at the base of Q_2?

17. In Figure 4, the voltage at the collector of Q_2 is found to be zero, but a 262-kHz signal passes through the receiver when applied to the base of Q_3. List possible causes of this condition.

18. The audio portion of an FM receiver is serviced by the same techniques employed in an AM receiver. True or False?

19. There is no essential difference between an AM and an FM detector circuit. True or False?

20. A varactor diode such as that in the afc circuit of Figure 6 changes capacitance when the voltage across it changes. True or False?

21. Would a measurement of zero volts (dc) on the collectors in the r-f or i-f sections of the receiver of Figure 6 indicate trouble?

22. The source of the agc voltage used in Figure 6 to control the gain of Q_1 is taken from the (a) ratio detector, (b) collector of Q_5, (c) base of Q_1.

23. In a ratio detector such as that shown in the receiver of Figure 6, the total voltage across C_{38} and C_{39} remains relatively constant but the ratio of voltage between these two capacitors varies at an audio rate. True or False?

24. Why must the signal level of the generator be kept low if the voltage across C_4 is used as an output indicator in Figure 6?

25. If dc voltage measurements appear normal in a given i-f stage but signal gain is below normal, what should be checked?

26. What is the purpose of D_1 in the receiver shown in Figure 6?

27. Varactor diodes are mechanically very stable. True or False?

28. What is the function of the varactor oscillator shown in Figure 7?

29. Referring to Figure 7, the crystal filters amplify weak signals. True or False?

30. In Figure 6, when the incoming i-f signal is exactly centered in the passband of L_9 what is the voltage at the junction of C_{38} and C_{39}?

31. When a sweep generator and oscilloscope are used to align an FM discriminator, at what frequencies should the markers occur?

32. At what point on the oscilloscope pattern shown in Figure 10 should the 10.7-MHz marker occur?

33. Tape recordings require an amplifier with more-than-normal high-frequency response because of the characteristics of the recording. True or False?

34. What is the function of balance control R_{12} in Figure 11?

35. Carbon tetrachloride should never be used to clean the iron oxide from a tape recorder head. True or False?

36. What two adjustments are available to ensure proper tape tracking in cartridge tape players?

37. What is the correct motor speed and the correct forward tape speed in cartridge tape players?

38. Is the transistor of Figure 12 operating as an amplifier or as a switch?

SUMMARY

The servicing procedures for automobile radios are quite similar to those for home-entertainment radios. Often, the most difficult part of the job is removing and installing the radio in the automobile.

In general, automobile radios are mechanically built better to withstand vibration and shock. Variable inductors are used to tune the r-f circuits rather than variable capacitors. Also, a low i-f, 262 kHz, is generally used in AM receivers to provide high i-f gain. A tuned r-f amplifier is employed to reduce image problems.

The basic service procedure is to inject an audio signal at the volume control. This separates the receiver into two sections, audio and r-f. Further signal injection in whichever section is defective will reveal the defective stage. Voltage and/or resistance measurements can then be employed to locate the defective component.

In recent years, many automobiles have been equipped with FM receivers. Although the frequencies are different, the servicing procedures are basically the same. Likewise, the basic service procedure holds for the cartridge tape players used in many automobiles today. Once a good service procedure is developed, it can be applied to almost any type of equipment.

PRACTICE EXERCISE SOLUTIONS

1. The power connection, the antenna lead and usually speaker leads must be removed.

2. First, disconnect all external leads. Then, remove knobs and shaft nuts. Unfasten the radio from the support brackets under the dashboard and remove it.

3. Inadequate filtering in the power supply being used to replace the car's battery or too high an internal resistance in the supply.

4. A shunt is put in parallel with the ammeter to change its full-scale reading to 20 amps rather than 10 amps. The voltmeter circuit is unchanged.

5. On 6 volts the system uses a center tap on the transformer and two diodes to form a full-wave rectifier. On 12 volts the center tap on the transformer is open and a full-wave bridge circuit employing all four rectifiers is used.

6. True

7. False—Almost all new auto radios use 262 kHz as the i-f.

8. All voltages in the radio will have the wrong polarity, and the radio will be inoperative. This can also result in damage to some of the circuit components.

9. (a) L_2—1600 kHz and (b) L_3—1600 kHz, both tuned to the frequency of the incoming station. (c) L_4—1862 kHz—262 kHz above the station. (d) L_5—262 kHz—the i-f frequency.

10. The avc voltage goes in the negative direction as the strength of the received signal increases. Thus, it subtracts from the positive voltage on the bases of Q_1 and Q_3 and reduces the gain of these stages.

11. (b) decreases the collector voltage of Q_6.—Reducing the Q_4 emitter voltage will increase current through this stage, reduce the base voltage on Q_5, thus reducing current there and increasing the base voltage on Q_6. Any increase in this voltage reduces the current through Q_6 and so reduces its collector voltage.

12. False—There will be no current through T_1 because it is shorted out by the path to ground through the shorted capacitor.

13. The current through Q_4 controls the base voltage on Q_5, and any decrease in the Q_5 base voltage causes less collector current in Q_5.

14. The collector and emitter voltages on Q_4, all voltages on Q_5, and all voltages on Q_6 would be abnormal.

PRACTICE EXERCISE SOLUTIONS (Continued)

15. The receiver would have no audio output. Inserting an audio signal at any base in the audio section would produce no output. Voltage measurements would be taken beginning at Q_6. Base voltage would be near normal, but the collector voltage would be zero. The emitter voltage would be almost the same as the base voltage because of the internal connection between the two. Checking directly across R_{22} would show it was open.

16. No—With this open circuit there is no collector voltage on Q_3, so no signal reaches the avc diodes.

17. L_4 or L_5 may be open. The printed circuit board may have an open between Q_3 and the 11.5-volt point of the power supply.

18. True

19. False—An AM detector is designed to respond to changes in amplitude, whereas an FM detector responds to changes in frequency.

20. True—The capacitance represented by this diode is dependent on the applied voltage.

21. No—All these collectors normally measure zero dc voltage.

22. (b) collector Q_5.—This signal voltage is rectified by D_3 and then applied to the base of Q_1.

23. True—The total voltage is held constant by the stabilizing action of the large electrolytic capacitor C_4. The ratio of the voltage across C_{38} and C_{39} changes at the same rate as the original audio modulation.

24. If the incoming signal is too strong, Q_5 serves as a limiter and the voltage across C_4 will reach some value and not rise any further with changes in gain of other stages or input signal stage.

25. Any bypass capacitors used in that stage.

26. D_1 is a zener diode used as a voltage regulator to maintain constant voltage levels on the emitters of Q_1 and Q_2.

27. True

28. The varactor oscillator provides a stable ac voltage. That voltage is later controlled, rectified and used to bias the varactor tuning diodes.

29. False—They are passive devices. The crystal filters replace i-f transformers and never need alignment.

De VRY INSTITUTE OF TECHNOLOGY
4141 BELMONT AVENUE, CHICAGO, ILLINOIS 60641

ONE OF THE
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7520A&B
EXAMINATION CHECK SHEET

NOTICE: To keep our lessons up-to-date, we add material to the texts from time to time, and make occasional changes in the examination questions. Therefore, when checking your answers with this check sheet, look at the code LETTER (A, B, C, etc.) on your examination sheet to determine which of the following groups of answers apply to the lesson which you have.

7520B

1. D - THE I-F FREQUENCY USED IN MOST CURRENT AM BROADCAST AUTOMOBILE RECEIVERS IS -- 262 kHz.
The use of a lower i-f frequency results in a higher stage gain.

2. A - IN AN AUTOMOBILE RECEIVER EMPLOYING PNP TRANSISTORS AND A NEGATIVE GROUND SYSTEM -- THE COLLECTORS ARE RETURNED TO GROUND.
To reverse bias the collector junction, the collector would be grounded and the emitter connected to the positive supply.

3. D - ASSUME THAT BOTH THE EMITTER AND BASE VOLTAGE OF Q_6 ARE HIGHER THAN NORMAL AND THE BASE VOLTAGE OF Q_5 IS ZERO IN THE CIRCUIT OF FIGURE 4. A PROBABLE CAUSE OF THE TROUBLE IS -- A SHORT IN C_{23}.
With a short in C_{23}, the base of Q_5 would be at zero volts. This would cut off Q_5 and raise its collector voltage, thus raising the Q_6 base voltage. This would cut off Q_6, raising its emitter voltage.

4. A - IF BOTH THE COLLECTOR AND EMITTER OF Q_2 IN THE CIRCUIT OF FIGURE 4 MEASURE ZERO VOLTS, THE TROUBLE IS LIKELY -- AN OPEN IN L_4.
With L_4 open, there would be no supply voltage applied to the Q_2 collector circuit.

5. D - IN THE CIRCUIT OF FIGURE 4, C_1 -- IS SET AT THE HIGH END OF THE BAND.
C_1 is the antenna trimmer. It is adjusted at the high end of the band with the receiver in place and connected to the regular automobile antenna.

6. A - D_2 IN THE CIRCUIT OF FIGURE 6 PROVIDES -- AFC ACTION.
D_2 is a voltage variable capacitance diode. The bias on this diode is controlled by the output of the ratio detector to keep the local oscillator on frequency.

7. A - THE MAJOR DIFFERENCE BETWEEN AM AND FM RECEIVERS IS THE -- DETECTORS.
The audio agc and i-f circuits are similar in AM and FM receivers, whereas the detectors are different.

8. C - WHAT WILL BE THE EFFECT IN THE CIRCUIT OF FIGURE 6 IF C_{22} SHORTS? -- THE LOCAL OSCILLATOR MAY DRIFT OFF FREQUENCY.
With C_{22} shorted, no afc voltage will be applied to the D_2 afc diode, and the oscillator may drift off frequency.

9. C - IN FIGURE 7, WHAT IS THE PURPOSE OF L_{210}? -- IT IS PART OF AN AC VOLTAGE DIVIDER.
The output of a highly stable oscillator is applied to an ac voltage divider consisting of L_{210} and L_{209}.

10. A - IF THE MOTOR GOVERNOR SWITCH IN FIGURE 12 LOCKS IN THE OPEN POSITION -- THE MOTOR WILL NOT RUN.
With the governor switch open, Q_7 will be cut off and no current will be supplied to the motor.

7520A

All explanations are the same as for 7520B except for that given below.

2. A - IN AN AUTOMOBILE RECEIVER EMPLOYING PNP TRANSISTORS AND A NEGATIVE GROUND SYSTEM -- THE COLLECTORS ARE GROUNDED.
To reverse bias the collector junction, the collector would be grounded and the emitter connected to the positive supply.

PRACTICE EXERCISE SOLUTIONS (Continued)

30. Zero.

31. 10.6 MHz, 10.7 MHz, and 10.8 MHz.

32. Exactly at the center point of the curve.

33. False—The low frequencies must be boosted, not the high frequencies.

34. The balance control is used to increase the gain in one channel while reducing that of the other channel to obtain the best balance and stereo effect.

35. True—Use alcohol or a commercial cleaner available for this purpose.

36. Height and azimuth adjustments.

37. Motor speed is generally 3000 rpm and tape speed is $3^3/_4$ inches per second.

38. It operates as a switch in the line between the motor and the battery. When the transistor is conducting, it acts as a closed switch or short, and when it is not conducting it is equivalent to an open circuit.

QUESTIONS

IMPORTANT—These instructions **MUST** be accurately followed to avoid loss, or errors in grading.

Indicate your answer on this sheet by filling in the box for the most correct answer to each question, as illustrated in the example below.

When all questions have been answered, place the answer card in the proper position to line up the boxes on the card with the boxes on the sheet.

Next, copy the complete lesson code into the space provided on the card, and fill in the answer boxes to correspond with those previously filled in on this sheet.

Before mailing, be certain your correct student number, name and address appear on the card.

LESSON CODE
7520B

Example: London is the capital of
A ■
B ☐
C ☐
D ☐
(A) England. (B) Russia. (C) China. (D) Germany.

1. A ☐ B ☐ C ☐ D ☒
The i-f frequency used in most current AM broadcast automobile receivers is
(A) 455 kHz. (B) 10.7 MHz. (C) 4.5 MHz. (D) 262 kHz.

2. A ☒ B ☐ C ☐ D ☐
In an automobile receiver employing PNP transistors and a negative ground system,
(A) the collectors are returned to ground. (B) the emitter resistors are returned to ground. (C) the collectors are connected to the positive supply. (D) the emitters are grounded.

3. A ☐ B ☐ C ☐ D ☒
Assume that both the emitter and base voltage of Q_6 are higher than normal and the base voltage of Q_5 is zero in the circuit of Figure 4. A probable cause of the trouble is
(A) a short in C_{22}. (B) an open C_{24}. (C) Q_5 has a base-emitter short. (D) a short in C_{23}.

4. A ☒ B ☐ C ☐ D ☐
If both the collector and emitter of Q_2 in the circuit of Figure 4 measure zero volts, the trouble is likely
(A) an open in L_4. (B) a short in C_8. (C) a short in C_9. (D) an open in R_7.

5. A ☐ B ☐ C ☐ D ☒
In the circuit of Figure 4, C_1
(A) sets the local oscillator frequency. (B) is the local oscillator padder. (C) is set at the low end of the band. (D) is set at the high end of the band.

6. A ☒ B ☐ C ☐ D ☐
D_2 in the circuit of Figure 6 provides
(A) afc action. (B) avc action. (C) agc action. (D) limiting.

7. A ☒ B ☐ C ☐ D ☐
The major difference between AM and FM receivers is the
(A) detectors. (B) audio circuits. (C) agc circuits. (D) i-f stages.

8. A ☐ B ☐ C ☒ D ☐
What will be the effect in the circuit of Figure 6 if C_{22} shorts?
(A) The receiver will be completely dead. (B) The audio output will be distorted. (C) The local oscillator may drift off frequency. (D) The local oscillator will be inoperative.

9. A ☐ B ☐ C ☒ D ☐
In Figure 7, what is the purpose of L_{210}?
(A) It varies the oscillator tuning. (B) To change the i-f frequency. (C) It is part of an ac voltage divider. (D) It prevents Q_{205} from oscillating.

10. A ☐ B ☒ C ☐ D ☐
If the motor governor switch in Figure 12 locks in the open position,
(A) the motor will not run. (B) the tape speed will decrease. (C) the tape speed will increase. (D) the motor speed will remain constant.

SERVICING INTERCOMS AND PA SYSTEMS

7525

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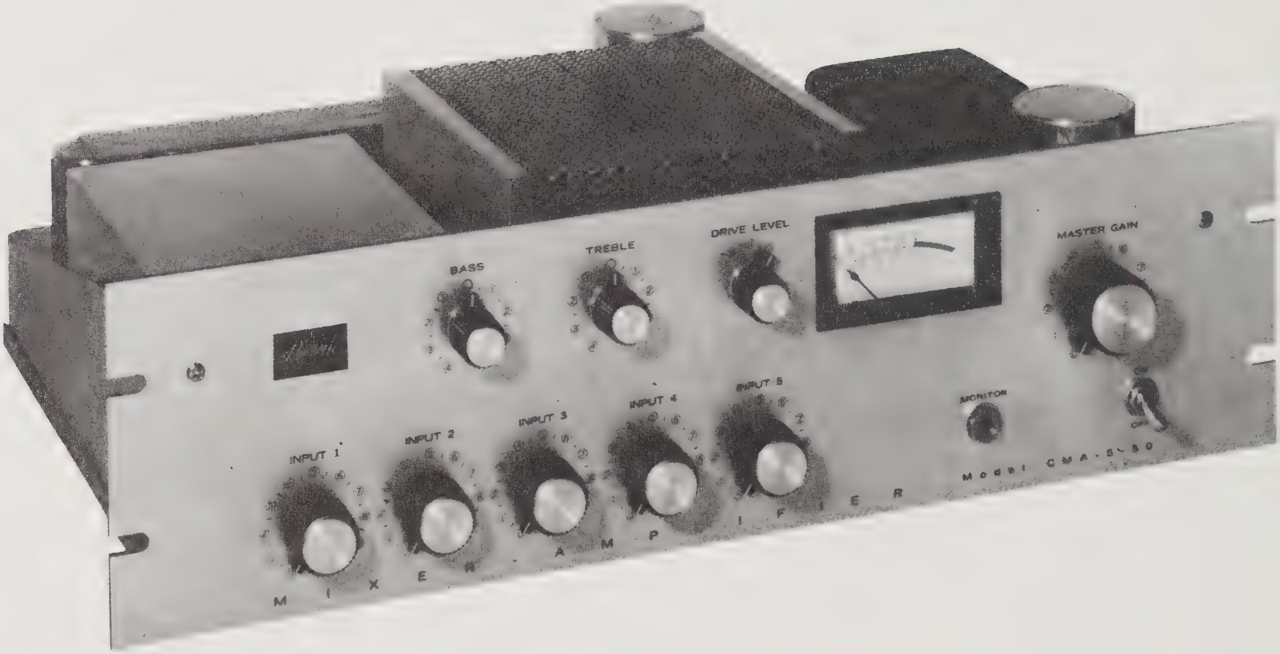

This mixer and control amplifier, designed for convenient rack mounting, provides all the required controls and power needed for a versatile public address sound system.

Courtesy R. T. Bozak Mfg. Co.

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> *Life is rich with opportunity, and you elect*
> *for yourself every morning whether the day*
> *will be fruitful of results or not.*
> *—Grenville Kleiser*

SERVICING INTERCOMS AND PA SYSTEMS

Often overlooked when considering opportunities in electronic servicing are the fields of public address systems and intercommunication equipment. Such equipment varies from small systems designed primarily for paging and intercommunications to units large enough to address huge crowds in a sports stadium. The units employed vary from simple amplifiers with a watt or two of output power and a limited frequency range to installations with hundreds of watts of output power, used to drive many speakers and capable of high-fidelity sound reproduction. In addition to permanent installations, there are portable public address systems available for use at outdoor gatherings at temporary locations such as group picnics or political meetings.

For the average service shop, public address and intercom equipment probably does not constitute a large part of the service business. It could, however, be raised to a more significant part of the total business. A few shops specialize in work of this type, doing both maintenance and installation work on permanent setups and providing portable public address systems for rental to clubs, civic groups and individuals.

INTERCOM SYSTEMS

Many businesses use intercom systems in both offices and factories for fast communication and paging purposes. The ability to reach personnel at many points throughout a building is a great convenience. Such installations usually consist of one or more master stations which can be used to select any other station in the system as a receiver, and a group of slave stations which provide talkback and listening facilities.

Most intercom systems now being manufactured use solid-state circuitry. However, some tube-type equipment is still in service. In most intercom systems, a single speaker reproduces the sound and also serves as a microphone for talking. In a wired system, each slave unit is connected to the master station by cable. The master station contains not only pickup and amplifying equipment, but also a switching system to allow selection of the stations to be called.

MASTER/SLAVE SYSTEM

Figure 1 shows a switching diagram of a typical intercom system which uses one master station and a group of substations, or slave units. The system

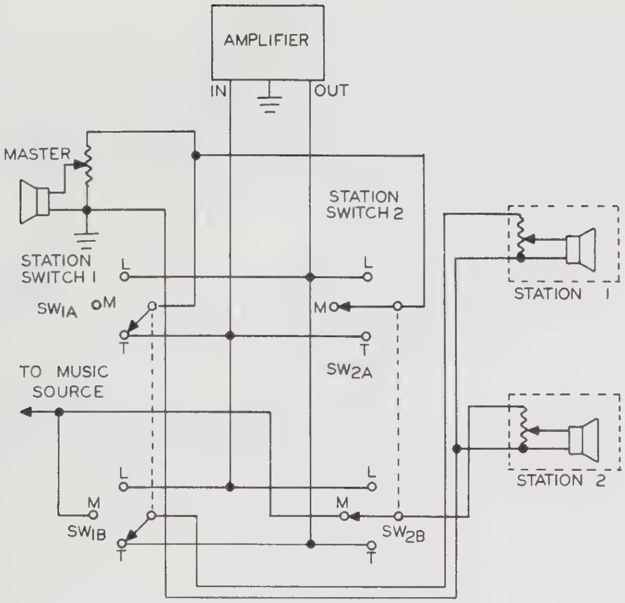


Figure 1

shown can also be used to distribute background music when not in use as an intercom or paging unit.

In an arrangement of this type, the master unit can be used to call any single station or all stations simultaneously. It can also receive replies from the station or stations called. The slave stations cannot originate calls. Only one amplifier is employed in this system, and it is associated with the master station.

Each slave station in Figure 1 consists of a speaker and a volume control. The volume control makes it possible to adjust the sound to the proper level for the background noise and size of the area where the station is located. In all such systems, the speaker is used both to reproduce the sound and as a dynamic microphone for talking back into the system. The switching arrangement determines which speaker is connected to the input and which is connected to the output. A two-wire line is required between each slave station and the master control. However, most systems of this type use a three-wire line to allow the communication between two slave units to be isolated from the master station speaker.

Switches SW_1 and SW_2 are used to communicate with Stations 1 and 2, respectively. These are two-pole, three-position lever switches which may be set in either the listen (L), music (M) or talk (T) position. In Figure 1, switch SW_1 is in the talk position, so the master can talk to Station 1. The signal path is from the master speaker, which now serves as a microphone, through SW_{1A} and the amplifier to SW_{1B}, and from SW_{1B} to Station 1. To receive a reply, switch SW_1 is set to the L position. The Station 1 speaker then serves as a microphone, and its signal passes through SW_{1B} to the input of the amplifier, and from the output of the amplifier through SW_{1A} to the master speaker. SW_2 is set to the music (M) position. Thus, Station 2 receives the music applied to the intercom system.

ALL-MASTER SYSTEM

Figure 2 shows a more elaborate switching arrangement that permits any station to originate calls to any point in the system. Here, each master station is entirely independent, including a separate amplifier and switching panel. Although this system is more versatile, it is also much more expensive.

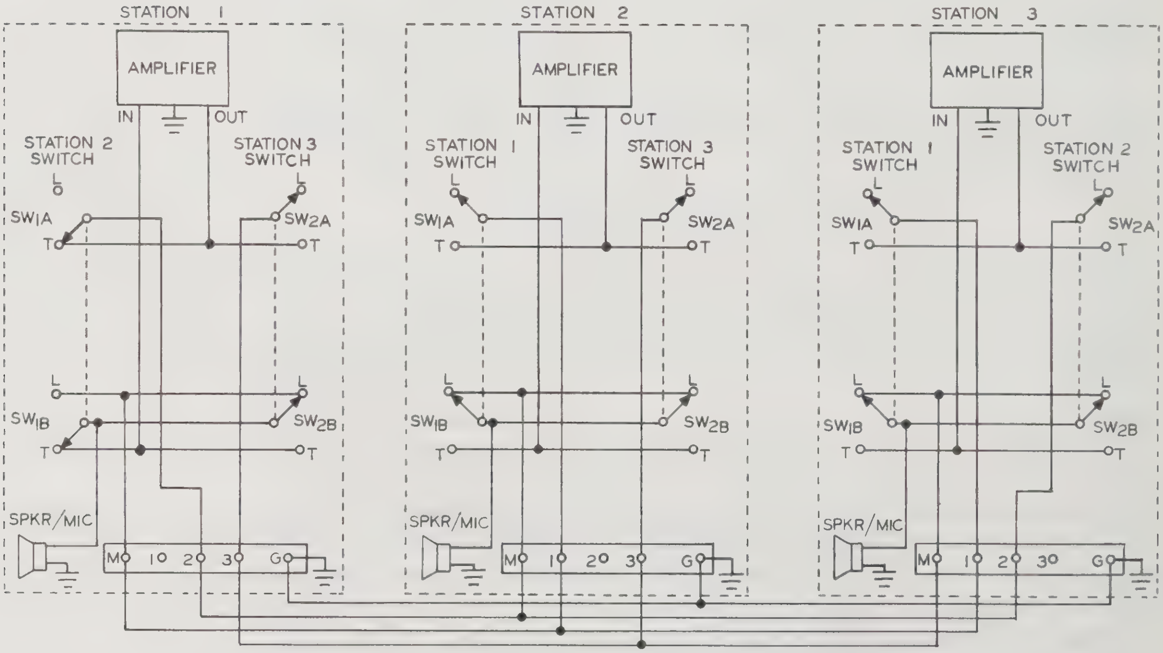


Figure 2

In this system, the individual units are identical. The various stations are established by selecting the connections on their terminal strips. For example, in Station 1 of Figure 2, terminals 2 and 3 go to the master (M) terminals of Stations 2 and 3, respectively. There is no connection to terminal 1 since this station has been designated as Station 1. Instead, the M terminal of Station 1 connects to terminal 1 on Stations 2 and 3.

The same applies for Stations 2 and 3. The M terminal of Station 2 connects to terminal 2 of Stations 1 and 3, and there is no connection to terminal 2 of Station 2. The M terminal of Station 3 connects to terminal 3 of Stations 1 and 2, and there is no connection to terminal 3 of Station 3. The common, or ground, terminals of all stations are connected together.

Figure 2 also shows how Station 1 would initiate a call to Station 2. Switch SW_1 in Station 1 is in the talk (T) position, and all other switches are in the listen (L) position. The speaker in Station 1 is connected through SW_{1B} to the input of the amplifier, and the amplifier output connects through SW_{1A} to terminal 2 on the terminal strip, through the connecting cable to terminal M on the Station 2 terminal strip, and through SW_{1B} to the Station 2 speaker.

In the arrangements of Figures 1 and 2, additional stations can be added up to the limit of switch positions on the control panel. In our examples, we have limited the number of stations shown, for simplicity. However, most master stations can handle a larger number of stations.

With the slave and master system of Figure 1, a two-wire line is required to each station. With the system of Figure 2, each station must be served by a cable containing one common line and one line for each station in the system. Thus, a five-station system similar to that of Figure 2 would use six-wire cable.

A master intercom for industrial use. A large number of stations can be selected by the row of lever-type switches.
Courtesy Rauland-Borg Corp.

INTERCOM AMPLIFIER

Figure 3 is a schematic diagram of a transistorized amplifier suitable for use in the master station of Figure 1 or for each unit in Figure 2. This amplifier includes three stages of amplification, followed by a push-pull power output stage. When the speaker is used as a microphone, input transformer T_1 provides the required impedance matching. After the intercom has been returned to the listen mode, the same speaker is matched to the output circuit by output transformer T_3.

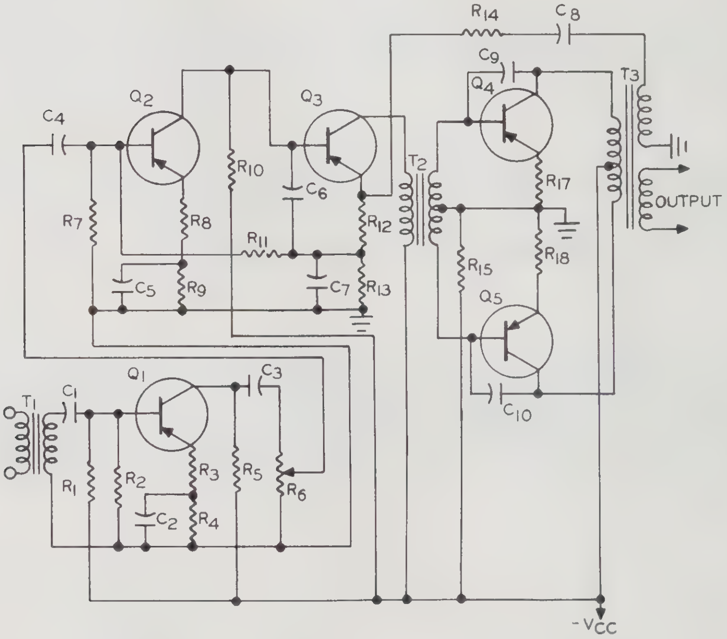


Figure 3

The input stage, Q_1, operates as a conventional common emitter amplifier. A portion of the Q_1 emitter resistance, R_3, is unbypassed to provide negative feedback. Q_2 and Q_3 form a direct-coupled amplifier. R_{11}, connected to the Q_2 base from the junction of R_{12} and R_{13}, provides feedback from the emitter circuit of Q_3 to base circuit of Q_2. If the average current through Q_3 increases, the base of Q_2 becomes more negative. This increases the current through Q_2, which, in turn, increases the voltage across R_{10}. This reduces the base voltage of Q_3, causing it not to conduct as heavily. This feedback helps to stabilize the operation of both the Q_2 and Q_3 stages, and prevents the thermal runaway of these stages.

Negative feedback is used in this amplifier to improve the audio quality. The voltage developed across the upper secondary winding on the output transformer is fed back to the emitter of Q_3 through C_8 and R_{14}. This voltage is 180° out-of-phase with the original signal voltage at the emitter, and thus serves as degenerative feedback.

Degeneration, or negative feedback, reduces the gain of an amplifier in proportion to the amplitude of the output signal. For example, if the basic amplifier has a tendency to attenuate high and low frequencies in comparison to midrange frequencies, there will be less feedback voltage at the high and low frequencies. Therefore, the amplifier gain increases at high and low frequencies, resulting in more uniform response over the entire audio-frequency range.

Negative feedback also reduces any distortion introduced within the feedback "loop" (the Q_3, Q_4 and Q_5 stages). This is because the signal fed back to Q_3 will contain distortion of opposite polarity and will cancel a large portion of the original distortion.

When an intercom speaker is used in the "talk" mode, sound waves striking the speaker cone cause the cone to vibrate. This moves the voice coil in the field of the speaker magnet, inducing an ac voltage in the voice coil at the frequency of the sound and at an amplitude proportional to the loudness of the sound. Which speaker acts as a MIC and which as a sound reproducer depends on the positions of the switches on the control panel.

The amplifier may be serviced in the same manner as any other audio amplifier. Using the signal substitution approach, you can feed a signal from an audio generator to the base of Q_1. If this signal does not produce an audio tone from the speaker, apply it to each base in turn, working toward the output, until you hear the sound in the speaker. Remember that with direct coupling, as in the Q_2 and Q_3 stages, trouble in one stage will also alter the voltages in the other.

If a unit works satisfactorily as a listening station but not as a talkback unit, the difficulty must be either in the switching setup or in the input components associated with transformer T_1. The switching unit can easily be checked with an ohmmeter. The interconnecting cables that run from one unit to another are connected to a terminal block behind the switch panel.

A slave unit contains only the speaker and volume control. The unit can be checked by connecting it as a speaker for any audio amplifier. To check the line between stations, you can substitute a known good speaker at the slave station end of the line, or short the two wires at one end and use an ohmmeter to check for continuity at the other end.

WIRELESS INTERCOM

The systems described up to this point require connecting cables between the various units. Wireless intercoms such as that of Figure 4 are also common. No interconnecting cables are required between units of a wireless system. The ac line serves to distribute the signal. The audio signal produced by the microphone is used to modulate a 200-kHz carrier, generated by an oscillator. The modulated carrier is coupled into the ac line. If another unit is connected to the same ac power line, it will receive the signal and produce an audible output.

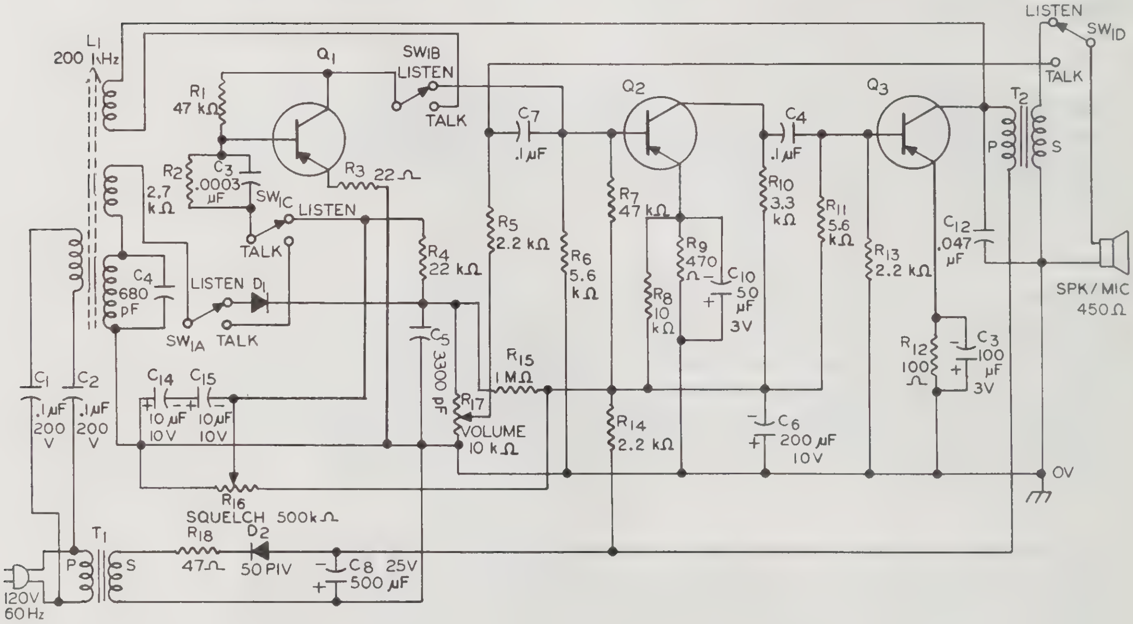


Figure 4

To analyze the operation of the unit of Figure 4, let us first consider it as a listening station. The various sections of switch SW_1 are then in the positions shown. The signal from the sending station is coupled from the ac line to L_1 through C_1 and C_2. C_4 and the bottom winding of L_1 are resonant at the 200-kHz frequency of the incoming signal. The signal voltage appearing across the bottom two windings is demodulated by diode detector D_1. The 200-kHz component is filtered out by C_5, and the audio portion appears across volume control R_{17}. The audio signal is fed from the movable contact of R_{17} through C_7 to the base of Q_2. Q_2 and Q_3 amplify the audio signal, and T_2 couples it to the speaker.

When switch SW_1 is in the LISTEN position, Q_1 develops a cutoff bias on Q_2 until a signal of predetermined amplitude is received. This is referred to as a squelch system, and its purpose is to provide quiet operation by eliminating noise when no 200-kHz carrier is being received. The squelch control, R_{16}, determines the bias on Q_1, which controls the amount of collector current of Q_2. Since the collector of Q_1 and the base of Q_2 are directly connected, the collector voltage of Q_1 controls the base voltage of Q_2. The squelch control is set so that no signal is passed if a 200-kHz carrier of the proper amplitude is not present. When a 200-kHz signal of sufficient amplitude is received, the positive voltage developed at the ungrounded end of volume control R_{17} is applied to the base of Q_1 through R_1; This voltage is sufficient to cut off Q_1. As a result, the base of Q_2 becomes more negative and Q_2 conducts normally.

Now let us consider the situation when the unit of Figure 4 is originating a signal and the other stations in the system are used for listening. Switch SW_1 must be set to the TALK position. The operator talks into the speaker and the voltage developed across the speaker voice coil is applied through C_7 to the base of Q_2. This signal is amplified by both Q_2 and Q_3 and used to modulate Q_1, which is now operating as a 200-kHz oscillator.

Notice that switch section SW_{1A} opens the detector input when transmitting, and connects the resonant circuit consisting of C_4 and the bottom two windings of L_1 through switch section SW_{1C} to the base of Q_1. Feedback occurs from the collector to the base of Q_1 because of the coupling between the upper two windings on L_1. This causes transistor Q_1 to oscillate at the frequency of the resonant circuit. The modulated signal from Q_1 is coupled to the ac line by the inductive coupling between the collector section of L_1 and the L_1 primary winding, and then through C_1 and C_2. The coil of L_1 is made adjustable so that the frequency of the carrier can be varied to put all the stations on the same frequency.

Troubles encountered in the wireless intercom shown in Figure 4 may be in either the audio or oscillator sections of the circuit. With switch SW_1 in the LISTEN position, if there is no sound from the speaker when an audio signal is introduced at the base of Q_3, the trouble must be in the Q_3 stage. Possibilities would include a faulty output transformer or speaker, shorted or open transistor, or an open circuit in the emitter or base of Q_3. Voltage readings and resistance tests could be used to pinpoint such troubles.

If there is sound from the speaker when an audio signal is applied to the base of Q_3, but not when the signal is applied to the base of Q_2, checks should include the effects of the squelch control circuit. Adjusting R_{16} should enable you to vary the base voltage of Q_2 both above and below the negative voltage on its emitter.

If the audio checks prove satisfactory, the next step is to apply a modulated 200-kHz signal across the two lower secondaries of L_1, and check the detector. A positive voltage should be developed at the ungrounded end of the volume control.

Failure of Q_1 to oscillate when the switch is in the TALK position would be shown by the lack of a positive voltage on the base of Q_1. This might result from trouble either in the tuned section of L_1, in the switching circuitry or with Q_1 itself.

Probably the most common complaint with a unit of this type is ac line noise while a signal is being received. It is not practical to filter out all the noise at the receiving end. If the source of the noise can be isolated, it can be more easily eliminated between the line and the appliance causing the noise. Commercial line filters are available for such purposes, and they usually prove adequate in eliminating noise from most small appliances.

PUBLIC ADDRESS AMPLIFIERS

Audio amplifiers used in public address system installations are available in a wide variety of power ratings and price ranges. Many public address amplifiers in service at the present time are of the vacuum tube variety.

This small solid-state PA amplifier is designed for mobile applications, and operates directly from the vehicle's 12-volt power supply.

Courtesy Lear Siegler, Inc.
Bogen Communications Div.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

INTERCOM SYSTEMS

MASTER/SLAVE SYSTEM

ALL-MASTER SYSTEM

INTERCOM AMPLIFIER

WIRELESS INTERCOM

1. What are the two functions of the speakers in the slave units of Figure 1?

2. In the intercom system of Figure 1, a slave unit can be used to call any other unit in the intercom system. True or False?

3. Assume that the master unit is calling Station 2 in Figure 1. Trace the signal path from the master speaker to the Station 2 speaker.

4. Assume that Station 3 is being used to call Station 2 in the all-master system of Figure 2. Trace the signal path.

5. When wiring an all-master intercom system such as that shown in Figure 2, how many wires would be required in the cable if there were 10 stations connected to the system?

6. If the primary winding of T_2 in Figure 3 were open, what would happen to the collector voltage of Q_2?

7. If the frequency response of either T_2 or T_3 of Figure 3 falls off at a rate such that a 5-kHz audio signal receives only half as much amplification as a 1-kHz audio signal, what will be the relative strength of the feedback voltage at these two frequencies and what effect will this have?

8. In Figure 3, will the negative feedback through C_8 and R_{14} reduce distortion in the Q_1 stage?

9. In the slave-master intercom system of Figure 1, would a listener at Station 2 normally hear a conversation between the master station and Station 1 when the switches are in the positions shown?

10. An intercom system consists of the amplifier of Figure 3 and the switching system of Figure 1. Both slave stations receive the music distributed when the intercom is not otherwise in use. The master station can call Station 1 but not Station 2. What parts of the system should you check to locate the fault?

11. **Why does the system of Figure 4 require a detector, whereas that of Figure 1 does not?**

12. **Assume that it is necessary to replace diode D_1 in the intercom of Figure 4. Is the polarity of the replacement diode important?**

13. **Which circuit components determine the frequency at which Q_1 will oscillate in the circuit of Figure 4?**

14. **Why is the slug in L_1 of Figure 4 made adjustable?**

$2\pi fC$

Since high power is usually one of the requirements of a PA system, tube amplifiers of the push-pull variety are very common in this type of service.

The amplifier used in a typical wired intercom installation might be adequate for some public address functions. Most PA amplifiers, however, are higher power amplifiers, usually with more versatile input control. Separate faders and mixer stages for at least two microphones, plus a tape player or turntable, are common.

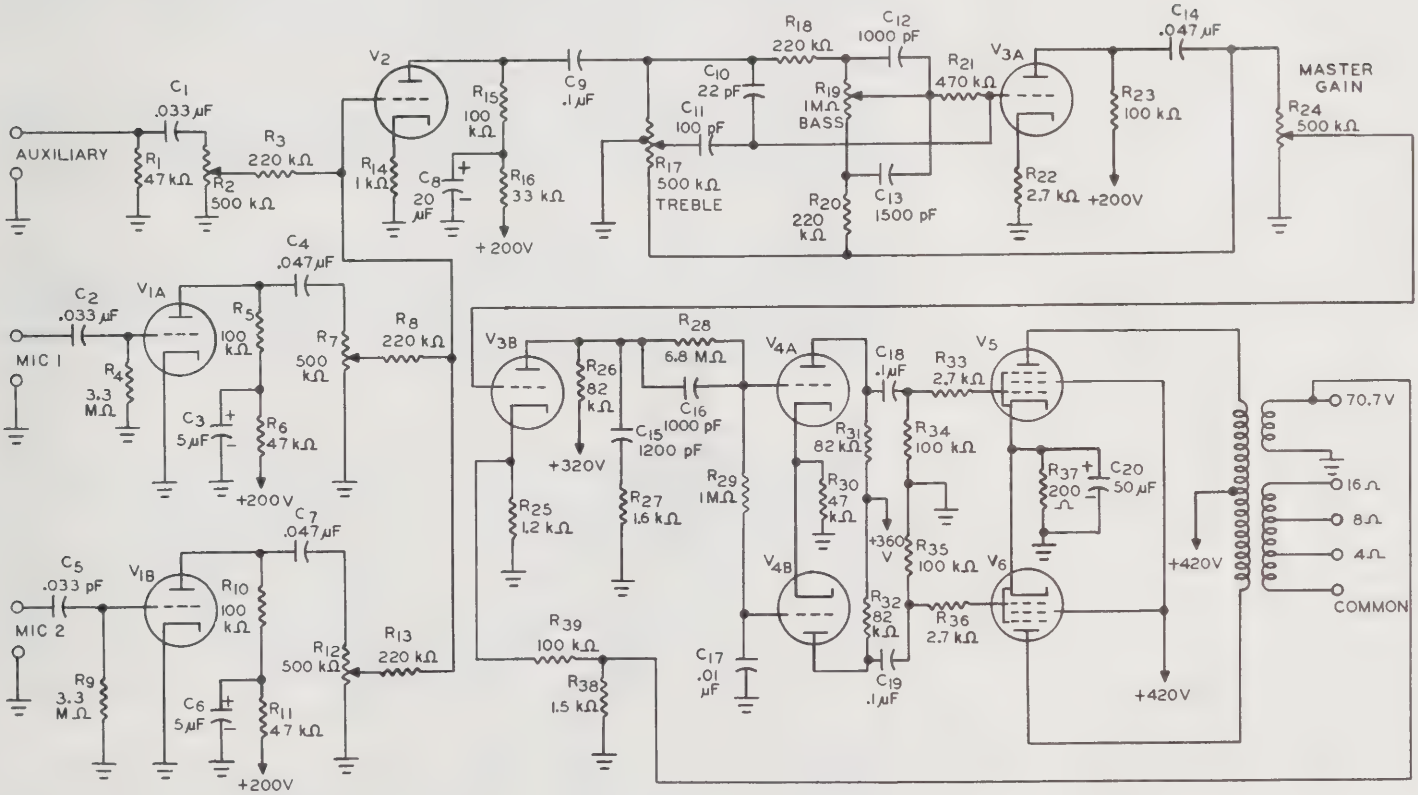


Figure 5

The amplifier of Figure 5 can accept two MIC inputs and an auxiliary input which might come from any preamplified source such as a tuner, tape recorder or phonograph. There are individual gain controls on the front panel for each input device. The 220K ohm resistors in series with each control prevent interaction between the controls. Signals from any or all of the inputs are combined at the grid of V_2, and the output of V_2 is fed to the tone control network.

Acoustical problems and different types of speaker systems in many meeting places require the amplifier to be able to provide something other than a flat frequency response. Reverberation from ceilings and walls may be severe at low frequencies, or feedback problems may arise if the microphones can pick up sound from the speaker system. Adequate control over the frequency response of the amplifier can help materially in dealing with these problems.

As is typical of most public address systems, the unit of Figure 5 employs separate bass and treble tone controls. Many tone control circuits are attenuators, and they should therefore be located in a part of the circuit that is followed by a stage providing adequate compensating gain at all frequencies. In this amplifier, the V_2 signal amplitude is more than that required to drive V_{3A}. The two tone controls determine what part of the signal actually reaches the V_{3A} grid. Let us consider how both a high-frequency signal and a low-frequency signal are affected by the controls.

Consider first a 5-kHz signal which is in the treble range. The network that controls this signal is redrawn in Figure 6A. In this drawing, the coupling capacitor values have been replaced by their reactances at 5 kHz to show more clearly the voltage divider action.

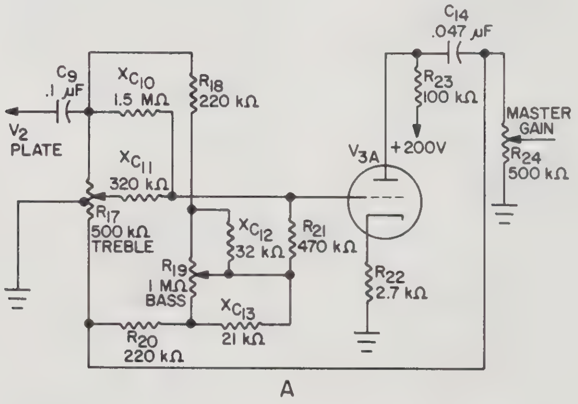


Figure 6

A small portion of this 5-kHz signal reaches the V_{3A} grid through the bass control by way of R_{18}, $X_{C_{12}}$ and R_{21}. This signal level is relatively constant, regardless of the setting of the bass control, since the control is bypassed by $X_{C_{12}}$ and $X_{C_{13}}$. However, the amplitude of this portion of the treble signal is not large enough to have much effect on this output.

Most of the treble signal is controlled with R_{17}. The treble path here is from C_9 through $X_{C_{10}}$, paralleled by the portion of R_{17} above its movable contact and through $X_{C_{11}}$ to the grid of V_{3A}. When the movable contact is near the top of R_{17}, $X_{C_{10}}$ and $X_{C_{11}}$ combined have a reactance at 5 kHz of about 250K ohms, and the path from the grid of V_{3A} to ground is greater than 700 kΩ. Consequently, about 70% of the incoming 5-kHz signal appears at the V_{3A} grid.

As the R_{17} movable contact is moved downward so that it is nearer to ground, the effective reactance in series with the V_{3A} grid is raised, the resistance from grid to ground is lowered, and less of the high-frequency signal voltage reaches the V_{3A} grid. When the movable contact is at the grounded point on the control, only about 10% of a 5-kHz signal is present at the V_{3A} grid, and about 90% of the signal is lost across $X_{C_{10}}$.

Suppose now that the treble control R_{17} is set so that the movable contact is below the ground tap. The effect is somewhat different since now we are altering the feedback network at high frequencies.

The negative feedback signal is taken from the top of the master gain control, R_{24}, and fed to the grid of V_{3A}. It is 180° out-of-phase with the original signal at this point. Consequently, any increase in this feedback reduces the gain of V_{3A}.

For a high-frequency signal, the feedback network consists of R_{20}, $X_{C_{13}}$ and R_{21} in series whenever the movable contact of R_{17} is above the ground tap. When the movable contact is below the ground tap, additional feedback is applied through $X_{C_{11}}$. The amount of feedback can be increased until the gain of V_{3A} barely exceeds 1. That is, the signal reaching gain control R_{24} is only as great as that reaching the grid of V_{3A}. This is, of course, much smaller than the signal entering the attenuator at C_9. We can therefore greatly reduce the amplitude of high-frequency signals, if desired.

The path for low-frequency signals is quite different. So little of this type signal follows the path we have described that the position of the treble control has virtually no effect on signals below 500 Hz.

Let us look at the circuit when a 100-Hz signal is present. Figure 6B shows the path for such a signal, with the capacitors again replaced by their reactances at this frequency. When the movable contact is at the top end of bass control R_{19}, C_{12} is effectively shorted, C_{13} is in parallel with the bass control, and the bass signal voltage divides between R_{18} and the resistance to ground, which is now equal to about one megohm. Thus, approximately 80% of the signal reaches the V_{3A} grid, and the remaining 20% is dropped across R_{18}.

Conversely, when the movable contact is at the bottom of R_{19}, C_{13} is shorted out and $X_{C_{12}}$ is in parallel with the control. The voltage divider now consists

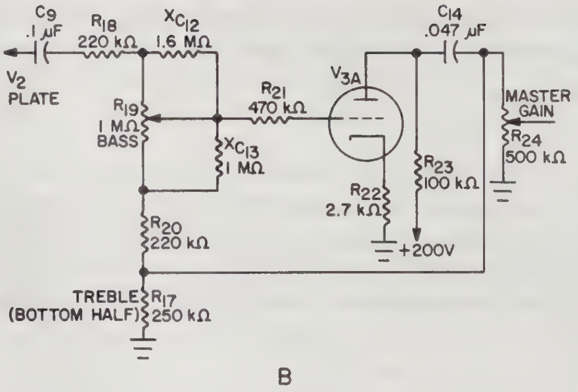


Figure 6

of R_{18} plus the parallel combination of $X_{C_{12}}$ and R_{19} as the loss element, and only R_{20} and the bottom section of treble control R_{17} in series to ground. About 70% of the bass signal is lost and 30% reaches the grid. The 470K ohm resistor, R_{21}, prevents the position of the bass control from affecting the treble response.

The feedback at low frequencies depends on the setting of the bass control. The loss element for bass is R_{20} and the portion of R_{19} that is below the setting of the movable contact. It is possible to reduce the gain to near 1 at low frequencies.

The master gain control of the circuit of Figure 5 is a standard volume control circuit between V_{3A} and V_{3B}. Since all inputs must pass through this stage, the control sets the overall level of the amplifier, regardless of which input is in use.

V_{4A} and V_{4B} serve as a phase splitter so that the signals delivered to the grids of V_5 and V_6 will be 180° out-of-phase. The grid of V_{4B} is at signal ground due to the bypassing effect of C_{17}. A positive-going signal at the grid of V_{4A} causes an increased voltage drop across common cathode resistor R_{30}. This causes current through V_{4B} to decrease because its grid is tied to signal ground by C_{17}. Therefore, the voltage at the plate of V_{4B} increases whenever the voltage at the plate of V_{4A} decreases. In this manner, a phase inverter is obtained to drive the output tubes, V_5 and V_6.

The final power output stage employs V_5 and V_6 in a push-pull circuit configuration. Here again, a common cathode resistor is used, but it is bypassed by a large electrolytic capacitor so that both cathodes are effectively at signal ground. The 2.7K ohm resistors in the grid circuits, R_{33} and R_{36}, are used as parasitic suppressors.

The amplifier negative feedback loop is from one secondary winding of the output transformer, back to the cathode of V_{3B}. This feedback improves the frequency response and tends to cancel any distortion occurring within the feedback loop. Notice that only a small portion of the output signal actually appears at the V_{3B} cathode because R_{39} and R_{25} form a voltage divider, with most of the feedback voltage dropped across R_{39}.

The taps on the output transformer secondary windings provide impedance matching for speakers of different impedances.

CONSTANT VOLTAGE LINE

For the amplifier that we have just studied, a separate winding is provided for what is called a 70.7-volt constant voltage line. This winding is used in many public address amplifiers, but is seldom used in home high-fidelity equipment. In some systems, the constant voltage is 25 volts, and some amplifiers provide both 25 and 70.7-volt taps on the output transformers.

To understand the need for such a line and to see how it works, let's consider an installation in which the same amplifier supplies sound to several locations. One of the speakers is located in a small room where the noise level is normally very low. Only a watt or two of power to the speaker will be adequate for this area. Another speaker from the same sound system is used to supply the same music to a large hall where several hundred people are eating. The larger size of the room plus the greatly increased background noise level requires that this speaker supply many more watts of sound power than needed in the small room. This is accomplished by using the constant voltage line and matching transformers for each speaker. The output impedance of a modern audio amplifier is almost always a low impedance source. A low impedance source is also a constant voltage source. Therefore, the 70.7-volt winding of the output transformer provides a constant voltage source. The use of a relatively high constant voltage source (70.7 or 25-volt winding) makes it easy to obtain different amounts of power for each speaker in the system by connecting each speaker to this line through its own matching transformer. The matching transformers usually have taps that allow different amounts of power to be applied to the speaker.

As long as the power required to drive all the speakers connected in parallel across the line does not exceed the power capability of the amplifier, each will receive the correct amount of power. Line matching transformers are also available with taps that allow use with speakers of different impedances. Specifications for a typical line matching transformer are as follows:

70.7-volt line to voice coil transformer wattage taps: 10, 5, 2.5, 1.25, .62 secondaries: 4, 8 or 16 ohms.

The formula for calculating the required primary impedance of a matching transformer is:

$$Z_P = \frac{E_P^2}{P_S}$$

where: Z_P is the primary impedance in ohms,
E_P is the primary voltage in volts, and
P_S is the secondary power in watts.

For use with a 70.7-volt line, this becomes:

$$Z_P = \frac{5000}{P_S}$$

Assume that one speaker requires 10 watts, and only 2 watts are required for another one. The first speaker requires a matching transformer whose primary impedance is:

$$Z_P = \frac{5000}{10} = 500\Omega$$

and for the second transformer:

$$Z_P = \frac{5000}{2} = 2500\Omega.$$

The transformers must also match these primary impedances to the voice coils of the speakers being used. Matching is accomplished by the proper transformer turns ratio.

The turns ratio (N) of the matching transformer is determined by dividing the primary impedance (Z_P) by the secondary impedance (Z_S), and then obtaining the square root of the quotient:

$$N = \sqrt{\frac{Z_P}{Z_S}}$$

An ordinary audio output transformer that is intended to match a speaker to a plate circuit of the desired primary impedance would work quite satisfactorily.

Advantages of the constant voltage line system are that the speakers may be of any impedance, and the power may be divided up in any desired manner as long as the total required power does not exceed the capabilities of the amplifier. Another important advantage is that any speaker may be removed from the line at any time without affecting the remaining speakers. This is not true where several speakers are connected in series or parallel across low impedance output transformer taps.

SERVICING PUBLIC ADDRESS AMPLIFIERS

The servicing problems encountered with public address amplifiers do not differ appreciably from those of any audio equipment. Remember though that the customer may be greatly inconvenienced by even a temporary loss of service.

If you maintain any such equipment on contract, or even on a regular basis without any contract, you should certainly stock all of the tubes used in the equipment. You should also be prepared to replace any other part of the amplifier on short notice.

When signal tracing in such an amplifier, the master gain control is a logical point to start. Any failure beyond this point will affect all signals. Any distortion, lack of high-frequency response, or loss of gain on a signal fed in at this point indicates trouble between the master gain control and the speaker. On the other hand, if the amplifier performs normally when a signal is injected at this point, you have cleared all stages from the master gain control to the output.

We will not attempt to analyze all the possible troubles in an amplifier, but let us look at a few in the stages beyond the master gain control. In the circuit of Figure 5, failure of V_{3B} or V_4 will result in no output when an audio signal is applied to the master gain control. If V_{4A} is working but V_{4B} is not, serious distortion will result, but some signal will be heard. The same is true if one of the output tubes fails, and the system is driven to high output levels.

Voltage checks in the amplifier should include plate, screen and cathode voltages of any stage that is suspected of malfunctioning. Note that with the large cathode resistor of V_{4A} and V_{4B}, the cathode voltage is unusually high. This is why the positive dc plate voltage of V_{3B} is applied through R_{28} to the grids of V_{4A} and V_{4B}.

The actual voltage on the grids of V_{4A} and V_{4B} is identical to the plate voltage of V_{3B}, since there is no dc path to ground and therefore no dc current through either R_{28} or R_{29}. However, as soon as a meter is connected to the grids of either V_{4A} or V_{4B}, there is a path to ground through the meter, and grid voltage cannot be measured accurately without a high input impedance meter. In this particular amplifier, measuring the voltage to ground at opposite ends of R_{28} would show a difference of about 35 volts, although measuring the voltage across R_{28} would indicate zero voltage.

Situations of this kind arise occasionally even with a high impedance meter, and with a typical 20,000 ohms-per-volt meter, they will occur often. The presence of the metering instrument must be taken into account when determining the difference between the observed reading and the actual voltage present.

Let us assume now that a defect occurs ahead of the master gain control, and signals inserted at the master gain control provide normal output. The tone control circuitry should be checked by feeding in a signal at C_9. To determine if both tone controls work normally, it is necessary to use both high- and low-frequency audio signals.

If the fault is before V_2, it should be relatively easy to find because there are three separate signal inputs, each with its own level control. Assume that signals applied to the MIC 1 input provide normal output, but the same signals applied to the MIC 2 input do not produce normal output. The trouble must be in some of the circuitry associated with V_{1B}. In this stage, voltage measurements and, if necessary, resistance measurements should isolate the trouble.

Remember that the trouble may be in the microphone or other input device. Switch the two input devices, and if the trouble moves from one channel to the other, replace the microphone. Repair of microphones usually should not be attempted in the field, except to check for faulty connection between the MIC and the amplifier. Also, check to make sure the cable is not open. If the trouble is with the MIC itself, and a simple repair does not seem possible, supply a replacement. Then, either return the defective microphone to the manufacturer for service, try a replacement element, or discard it, whichever seems appropriate.

As in all electronic servicing, the key to efficient troubleshooting is a systematic isolation of the affected stage, followed by point-by-point measurements to determine the defective component.

SELECTING THE PROPER MICROPHONE

In selecting and installing any public address system there are other important considerations besides providing enough amplifier power to fill the hall or outdoor area involved. We have already mentioned versatility in the input circuit to handle a variety of signal sources. An amplifier intended for use by a single lecturer, such as in a system built into a speaker's lectern, does not require multiple inputs or faders. On the other hand, trying to cover a choral group with a single microphone is rarely satisfactory.

Another important consideration is frequency response. The cost of true high-fidelity equipment would certainly not be justified if the amplifier is to be used only for paging. A response of about 100 to 5000 Hz is adequate for paging. For musical reproduction, somewhat better fidelity is required. However, there is no point in using an expensive high-fidelity amplifier and then employing speakers which have limited frequency response. Adequate musical reproduction for most systems can be obtained with amplifiers which have a relatively flat frequency response from 100 to 18,000 Hz.

The microphone and the speakers are two other parts of the public address installation which deserve careful attention. Microphones used in public address applications vary widely in their characteristics, depending on the purpose for which they are designed. For example, an entirely different type of microphone is used in applications that require only voice pickup over small distances, compared to a MIC that is required to pick up a full orchestra in a large hall.

Microphones differ in impedance, output level, frequency response, ability to cancel noise and sound pickup pattern. Microphone impedances may vary from 50 ohms to 50,000 ohms. Many MIC's can be connected for either high or low impedance use. Where long connecting cables are used, a low impedance MIC will have less loss of high frequencies and less noise pickup on the line. Most PA systems use low impedance microphones except for those hand-held types intended for voice operation.

Microphone frequency response may vary from those that have a rapid fall-off above 3000 Hz to those capable of flat response beyond 15,000 Hz. Output levels are usually specified as minus a given number of decibels. This means that the MIC output must be amplified by that many dB to reach the reference power level of 1 milliwatt. Most MIC's have output levels between −50 and −60 dB.

These low output levels indicate that a great deal of power amplification is required between the MIC and the speaker system. However, most amplifiers have sufficient gain for use with MIC's that have output levels of only −60 dB.

The pickup pattern of a given microphone is quite important in public address systems. Most microphones currently used in PA systems have some form of cardioid (heart-shaped) pickup pattern, like that shown in Figure 7. The line surrounding the microphone in this figure represents points at which a sound of equal intensity would produce equal voltage output from the microphone. If the sound source is outside this area, the MIC's pickup falls off rapidly.

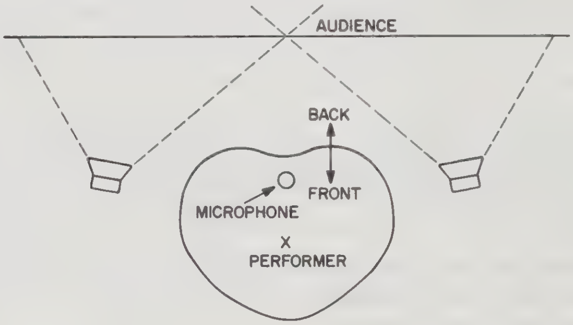


Figure 7

Notice that in this typical pattern, the area behind the MIC has very little pickup. This is highly desirable in public address installations, since it prevents the MIC from picking up sound from the loudspeakers (acoustic feedback). If the MIC had equal pickup in all directions, the sound from the speakers, even at a considerable distance from the MIC, would be louder than the original sound. Acoustic feedback would occur, and intelligible reproduction would be hard to achieve.

For most PA applications, a dynamic MIC with a cardioid pattern is the most appropriate selection. Crystal and ceramic MIC's are also used for some close-talking applications where feedback is a less severe problem. In general, these types provide higher output levels but less directional pickup. Most ceramic MIC's do not have sufficient frequency response for high-fidelity music reproduction. They are sometimes selected for hand-held applications because they are less delicate than dynamic microphones and will stand greater abuse. They are also considerably less expensive than good quality dynamic microphones. There are other types of microphones in common use, but they are seldom employed in PA system applications.

LOUDSPEAKERS

The loudspeakers used in public address installations also vary widely in their characteristics. An outdoor speaker installation for a sports stadium presents different problems than an installation intended for background music in a restaurant.

For a stadium, high-efficiency horn speakers capable of handling high power and concentrating the sound in the given area are desirable. Frequency response here is much less important than the efficient conversion of electrical power to sound. For a restaurant, wall baffles with relatively low-power cone-type speakers would be placed at several points in the room. Relatively good frequency response is a requirement for these applications.

All types of speakers are relatively inefficient devices. An unmounted cone speaker may have a very low efficiency, usually below 5%. A baffle raises the efficiency somewhat, but it is still lower than desirable. A good baffle mounting with the directional characteristics might achieve 20% efficiency in

The reflex trumpet shown above is designed for both indoor and outdoor applications. The reflex design of the speaker provides an efficiency of about 35%.

Courtesy Lear Siegler, Inc.
Bogen Communications Div.

converting electrical power consumed by the speaker into actual acoustical power. With use of a highly directional horn that confines the sound to a narrow area, efficiency can be boosted to 35% or more.

In placing loudspeakers to cover a given audience, there are several factors to consider. As far as possible, try to achieve even distribution of sound throughout the auditorium. Avoid making the volume uncomfortably loud near the front of the auditorium in order for those in the rear to be able to hear.

On the other hand, if a lecturer or performer can be seen by the audience, it is desirable for the voice to sound as though it comes from the stage. It is quite distracting to watch a performer far in front of you while hearing his voice from behind your shoulder.

For outdoor installations, it is obviously important to choose a speaker system which will not deteriorate due to weather. Metal or weatherproof plastic horns usually are best for use in these systems.

An additional consideration in the selection and placement of speakers is the acoustical characteristics of the area covered. In locations where sound distribution was not an architectural consideration, severe limits may be imposed on the system that is used. Reverberation of sound from hard, reflective surrounding surfaces may cause echoes which can greatly reduce intelligibility. Conversely, draperies tend to absorb sound and reduce reverberation.

Echo effects also occur if sound is heard from two different speakers and one of them is considerably farther away from the listener than the other one is. This is a rather common fault in public address systems in sports arenas. Use of directional horns which confine the projected sound to relatively narrow beams will help. Reducing the difference in distance between speakers will also help. If directional horns to serve two adjacent sections of a sports audience are mounted on the same pole and angled to cover different directions, there is much less echo effect than if the two speakers are separated by 100 feet and both pointed inward at this listening area.

A special type of speaker used in many theaters is the sound column, or line radiator. It consists of a number of cone speakers, mounted one above the other in a vertical column. This arrangement results in wide angle horizontal sound dispersion but very limited vertical dispersion. All the sound power is concentrated to about 20 to 30 degrees vertical coverage. This reduces reverberation problems and also leads to more even sound levels throughout the hall.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

PUBLIC ADDRESS AMPLIFIERS

CONSTANT VOLTAGE LINE

SERVICING PUBLIC ADDRESS AMPLIFIERS

SELECTING THE PROPER MICROPHONE

LOUDSPEAKERS

15. In the circuit of Figure 5, why is there no amplifier between the auxiliary input and R_2, as there is between MIC 1 and R_7, or MIC 2 and R_{12}?

16. When the treble control in Figure 5 is below the center ground tap, does the feedback voltage increase or decrease with further rotation of the control away from ground?

$\frac{1}{2\pi fC}$ $\frac{10^{12}}{6.28 \times 22}$

17. Calculate the reactances of C_{10} and C_{11} in Figure 5 at 100 Hz, and indicate why the setting of the treble control has little or no effect on bass response.

$$\begin{array}{r} 6.28 \\ \times 22 \\ \hline 1256 \\ 1256 \\ \hline 13816 \end{array}$$

18. When bass control R_{19} is exactly at its mid resistance point (500K ohms above and 500K ohms below the sliding contact), calculate the impedance from the movable contact of the control to ground, for a 100-Hz signal. Consider only the lower half of the treble control, as shown in Figure 6B.

$I = \frac{E}{R}$

10 10^7

1.4

19. In what manner would you connect four 8-ohm speakers to the 8-ohm tap on the output transformer in the amplifier of Figure 5?

$P = \frac{E^2}{R}$

$14 \overline{)100}$ 70 MΩ

20. Calculate the correct primary impedance and turns ratio for a line matching transformer that is to deliver 10 watts to a 4-ohm speaker from a 70.7-volt constant voltage line.

$40 = \frac{x^2}{4}$

21. When more than one speaker is connected to a constant voltage line, are they connected in series or in parallel?

6

22. Assume that C_{19} in the amplifier of Figure 5 is open. Would there be any output from the speaker?

23. In Figure 5 would you expect to measure the same voltage between the grid of V_{4A} and ground and between the grid of V_{4B} and ground?

24. Assume C_{10} is open. What would happen to the operation of the amplifier of Figure 5?

25. Assume that R_5 is open. What happens to the operation of the amplifier of Figure 5?

26. A certain ceramic microphone has an output rated at −50 dB and a certain dynamic microphone is rated at −56 dB. Which of these MIC's produces the most voltage at the input to the amplifier?

27. A microphone with a cardioid pickup pattern is usually a better choice for public address work than one having a circular pickup pattern. True or False?

28. The efficiency of a baffle-type speaker is usually higher than that of a directional horn speaker. True or False?

29. What are two common causes of echo from speaker systems?

30. A sound column provides wide angle horizontal dispersion of sound, but limited vertical dispersion. True or False?

This column loudspeaker system is designed to provide high output over a wide horizontal and limited vertical listening area.

Courtesy R. T. Bozak Mfg. Co.

SUMMARY

Servicing public address systems and intercom devices for business places provides a source of extra income for the service shop which actively seeks this business. Such devices are not difficult to service, and they present few unique problems.

An important consideration when dealing with this equipment is the necessity of providing prompt service. The customer is often greatly inconvenienced or even unable to conduct his normal business while the device is inoperative. You should be prepared to provide some substitute device when his equipment cannot be promptly restored to working order.

Wired intercom systems usually consist of one or more master stations containing a listen-talkback speaker, an audio amplifier and switching section, and a group of slave stations which may or may not be able to originate calls.

In a system involving a single master control and a group of slave stations, each slave station must be connected to the master by a single pair of lines. When each station is to be independent and able to call all other stations, the interconnecting cables require one common lead and one lead for each station in the system.

Wireless intercom systems usually make use of the ac line wiring to achieve signal distribution. In such a system, the audio signal modulates an oscillator in the low r-f range (200 kHz, for example) which serves as a carrier for distributing the signal. The listening device must then include a detector for recovering the original audio signal.

Public address amplifiers are usually high-power systems with facilities for handling a variety of inputs. Most systems designed for public address work provide individual front panel control of at least three or four inputs and the ability to mix signals from each source. Separate bass and treble tone controls are also commonly provided.

Output circuits for public address systems usually include a multiple tap transformer for properly matching a variety of speaker loads. Generally, one set of transformer taps is designated as a constant voltage source of either 70.7 volts or 25 volts.

When using a constant voltage line, each speaker must be equipped with a matching transformer. The advantages of such a system are that varying amounts of power can be provided to the various speakers over the same line, and each speaker can be connected or disconnected without affecting the output from the remaining speakers as long as the total power used by all speakers does not exceed the capabilities of the amplifier. This arrangement also permits the use of a considerable number of speakers without causing load impedance to be so low that it overloads or damages the amplifier.

In selecting microphones for sound systems, important considerations are impedance, frequency response and directional pickup characteristics. A less critical area of difference is voltage output. Where high-fidelity reproduction is important, a dynamic microphone is usually selected. Crystal or ceramic MIC's are often used with paging systems because they are less expensive than dynamic MIC's, and the ceramic MIC's are also more rugged.

Speakers for public address work include a variety of horn types and baffle-mounted cone speakers. Selection is based on the acoustics of the area served, the noise in the location, and the need to protect against weather in outdoor installations.

PRACTICE EXERCISE SOLUTIONS

1. The speakers reproduce the sound when the slave units receive calls, and are used as microphones when the slave units are used to answer the calls.

2. False—The slave units in this system cannot originate calls. They must first be called by the master station.

3. Switch SW_2 must be in the T position. The path is from the master speaker through SW_{2A} to the amplifier input, and from the amplifier output through SW_{2B} to the Station 2 speaker.

4. Switch SW_2 of Station 3 is in the T position and all other switches are in the L position for this call. The signal path is from the Station 3 speaker through SW_{2B} to the amplifier, and from the amplifier through SW_{2A} to terminal 2 on the terminal strip, through the cable to terminal M on the Station 2 terminal strip, and through SW_{1B} to the Station 2 speaker.

5. 11 wires.—Such a system requires one common wire, and one wire for each station in the system.

6. The collector voltage of Q_2 would increase toward the value of $-V_{CC}$. Since there is no collector current through Q_3, there is almost no voltage drop across R_{13}, and very little voltage on the base of Q_2. With a very small base voltage, transistor Q_2 will approach cutoff, and there will be only a very small voltage across R_{10}.

7. There will be only half as much feedback voltage at 5 kHz. Since the feedback voltage reduces the gain of Q_3, there will now be more amplification of the 5-kHz signal than the 1-kHz signal, and the output of the two signals will be more nearly equal.

8. No—Negative feedback can only reduce distortion developed within the feedback loop.

9. No—In this system, only Station 1 is connected to the output of the master unit with the switches in the positions shown.

10. The Station 2 switching network in the master control and the connections to it are the only possibility. Station 2 and its line must be all right because it receives the background music. The amplifier and the input circuits must be all right because the master can call Station 1. This leaves only the Station 2 switching circuit.

11. In the system of Figure 4, the audio signal is used to modulate a 200-kHz r-f carrier. To recover the original audio signal, a detector is required. No detector is required in Figure 1 because the audio signal is transferred directly from one unit to another.

PRACTICE EXERCISE SOLUTIONS (Continued)

12. Yes—The audio portion of the circuit would work properly with the diode connected either way, but in order for the squelch circuit to work properly, the diode must produce a positive-going voltage at the top of volume control R_{17} to cut off Q_1 when a signal is received. For this reason, the cathode of the diode must be connected to the volume control.

13. C_4 and the bottom winding of L_1.

14. L_1 is adjustable so that all of the stations in the system can be made to oscillate at the same frequency. The exact frequency is not too critical, as long as all stations are tuned to the same frequency.

15. The auxiliary input signal from a tuner, tape player or phono player is larger than that from the MIC's, and less amplification is required.

16. The feedback voltage increases.

17. At 100 Hz, C_{10} has a reactance of about 70 megohms and C_{11} about 15 megohms. Being in parallel with the bass circuit, which has a total reactance to ground of less than 2 megohms, these high reactances have virtually no effect on the bass signals.

18. The circuit consists of $X_{C_{13}}$ (1 megohm) in parallel with half of R_{19} (500K ohms) plus R_{20} (220K ohms) plus half of R_{17} (250K ohms). The total is approximately 800K ohms.

19. Connect two sets of two series speakers in parallel, or two sets of two parallel speakers in series.

$1 + \frac{1}{2}$

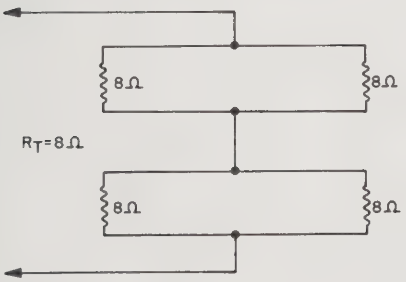
$1 + 2 = \frac{1}{\cancel{x}}$

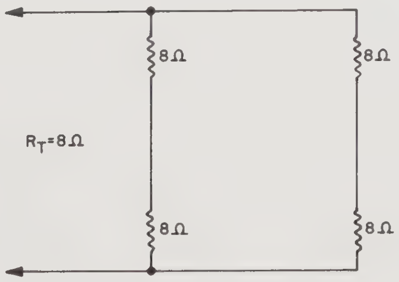
$3 = x$

$1 + \frac{1}{2} = \frac{1}{x}$

~~3~~ 2/3

333
~~667~~
220
250
803





20. The primary impedance is 500 ohms, and the turns ratio is 11.18 to 1.

$$Z_P = \frac{5000}{10} = 500 \text{ ohms} \qquad N = \sqrt{\frac{500}{4}} = 11.18 \text{ to } 1$$

In practice, a turns ratio of about 10 to 1 would be adequate.

DE VRY INSTITUTE OF TECHNOLOGY
4141 BELMONT AVENUE, CHICAGO, ILLINOIS 60641

ONE OF THE
BELL & HOWELL SCHOOLS

7525A
EXAMINATION CHECK SHEET

7525A

1. C - IN A WIRED INTERCOM SYSTEM IN WHICH EACH STATION CAN CALL ANY OTHER STATION, THE CONNECTING CABLE REQUIRES -- ONE MORE WIRE THAN THERE ARE STATIONS.
An all-master system such as this one requires a cable for each station containing one line for each station plus a common line. In a master-slave system, each station requires a two-wire line regardless of the number of stations.

2. C - IN A WIRELESS INTERCOM INSTALLATION, EACH UNIT MUST CONTAIN -- BOTH A MODULATED OSCILLATOR AND A DETECTOR.
The audio signal modulates the carrier in the modulated oscillator and is demodulated in the detector.

3. B - MOST HIGH-QUALITY PUBLIC ADDRESS SYSTEMS INCLUDE -- TONE CONTROL CIRCUITS AND INDIVIDUAL GAIN CONTROLS FOR EACH INPUT CIRCUIT.
Individual level controls permit matching the levels of the various inputs. The tone controls are used to tailor the response of the system to the room acoustics.

4. C - TO CONNECT FOUR 8-OHM SPEAKERS TO A PUBLIC ADDRESS SYSTEM YOU WOULD -- CONNECT TWO PARALLEL PAIRS OF TWO SPEAKERS IN SERIES ACROSS THE 8-OHM OUTPUT.
Connecting two 8-ohm speakers in series produces 16 ohms. Two 16-ohm speaker systems in parallel produces an impedance of 8 ohms.

5. C - A 70.7-VOLT CONSTANT VOLTAGE OUTPUT FROM A PUBLIC ADDRESS AMPLIFIER PERMITS -- SPEAKERS OF VARIOUS WATTAGES TO BE CONNECTED IN PARALLEL.
With a constant voltage line, speakers can be connected in parallel without regard to impedance. However, the total power output of the amplifier must not be exceeded by connecting too many speakers.

6. B - A MICROPHONE WITH A CARDIOID PICKUP PATTERN IS OFTEN DESIRABLE IN PUBLIC ADDRESS SYSTEMS BECAUSE -- IT REDUCES FEEDBACK PROBLEMS.
A cardioid pattern microphone has maximum pickup in only one direction. By positioning the microphone, pickup from the speakers and the resultant feedback is eliminated.

7. D - THE PUBLIC ADDRESS AMPLIFIER OF FIGURE 5 PROVIDES ISOLATION BETWEEN INPUT CONTROLS BY THE USE OF -- RESISTORS IN SERIES WITH THE VARIABLE CONTACTS ON THE CONTROLS.
This type of mixer circuit is sometimes called a "passive" or "dry" mixer since no tubes or transistors are employed.

8. A - IN THE AMPLIFIER OF FIGURE 5, V_4 SERVES PRIMARILY AS A -- PHASE INVERTER.
This phase inverter stage provides the desired 180° out-of-phase input signals for the push-pull amplifier stage.

9. D - A SOUND COLUMN OR LINE RADIATOR IS OFTEN USED IN THEATERS PRIMARILY BECAUSE IT -- REDUCES REVERBERATION AND GIVES MORE EVEN AUDIENCE SOUND COVERAGE.
The sound column or line radiator concentrates the sound to provide a wide horizontal dispersion angle but a narrow vertical dispersion angle.

10. D - MOST HIGH-POWER PUBLIC ADDRESS SYSTEMS IN OUTDOOR INSTALLATIONS USE -- DIRECTIONAL HORN SPEAKERS.
Directional horn speakers concentrate the sound to provide greater coverage.

PRACTICE EXERCISE SOLUTIONS (Continued)

21. Always in parallel.—Connecting or disconnecting one has no effect on the other.

22. Yes—The output signal would be distorted, and not at full power, but V_5 would still amplify, resulting in some output.

23. Not quite.—The actual voltage is the same, but the path to ground provided by the meter would cause current through R_{29}. As a result, the grid of V_{4B} would read lower than that of V_{4A}.

24. There will be little or no change in the bass response, but the high-frequency response would fall off. When the treble control is near the midpoint, almost no highs reach the grid of V_{3A}.

25. The MIC 1 input is dead. All other inputs work normally. Checks at V_{1A} will show no plate voltage.

26. The ceramic microphone.—The dB rating is always a negative number, and therefore the larger the number, the smaller the actual voltage produced.

27. True—There is less feedback trouble with the cardioid MIC.

28. False—A horn-type speaker is a more efficient device.

29. Echoes occur as a result of reverberation or reflection from hard, smooth walls, and as a result of sounds reaching the listener from two or more speakers at different distances.

30. True

QUESTIONS

IMPORTANT—These instructions **MUST** be accurately followed to avoid loss, or errors in grading.

Indicate your answer on this sheet by filling in the box for the most correct answer to each question, as illustrated in the example below.

When all questions have been answered, place the answer card in the proper position to line up the boxes on the card with the boxes on the sheet.

Next, copy the complete lesson code into the space provided on the card, and fill in the answer boxes to correspond with those previously filled in on this sheet.

Before mailing, be certain your correct student number, name and address appear on the card.

LESSON CODE
7525A

Example: A spotted animal native to Central and South America is the
(A) lion. (B) leopard. (C) tiger. (D) jaguar.
A ☐
B ☐
C ☐
D ■

1. A ☐ B ☐ C ☒ D ☐
In a wired intercom system in which each station can call any other station, the connecting cable requires
(A) a total of three wires, regardless of the number of stations. (B) one less wire than there are stations. (C) one more wire than there are stations. (D) two wires for each station.

2. A ☐ B ☐ C ☒ D ☐
In a wireless intercom installation, each unit must contain
(A) both a speaker and a separate microphone. (B) noise limiter circuits. (C) both a modulated oscillator and a detector. (D) avc and afc circuits.

3. A ☐ B ☒ C ☐ D ☐
Most high-quality public address systems include
(A) stereo amplifiers. (B) tone control circuits and individual gain controls for each input circuit. (C) provisions for mobile operation. (D) no output transformer.

4. A ☐ B ☐ C ☒ D ☐
To connect four 8-ohm speakers to a public address system you would
(A) connect all four in parallel across the 8-ohm output. (B) connect all four in series across the 8-ohm output. (C) connect two parallel pairs of two speakers in series across the 8-ohm output. (D) connect all four in parallel across the 16-ohm output.

5. A ☐ B ☐ C ☒ D ☐
A 70.7-volt constant voltage output from a public address amplifier permits
(A) connection of many speakers in series. (B) use of additional input sources. (C) speakers of various wattages to be connected in parallel. (D) exceeding the rated output power of the amplifier.

6. A ☐ B ☒ C ☐ D ☐
A microphone with a cardioid pickup pattern is often desirable in public address systems because
(A) it picks up sound at greater distances. (B) it reduces feedback problems. (C) it has better fidelity. (D) it requires less amplification.

7. A ☐ B ☐ C ☐ D ☒
The public address amplifier of Figure 5 provides isolation between input controls by use of
(A) matching transformers. (B) a master gain control. (C) cathode follower stages. (D) resistors in series with the variable contacts on the controls.

8. A ☒ B ☐ C ☐ D ☐
In the amplifier of Figure 5, V_4 serves primarily as a
(A) phase inverter. (B) high-gain voltage amplifier. (C) cathode follower for impedance matching. (D) power amplifier.

9. A ☐ B ☐ C ☐ D ☒
A sound column or line radiator is often used in theaters primarily because it
(A) has better fidelity. (B) is virtually weatherproof. (C) requires less power. (D) reduces reverberation and gives more even audience sound coverage.

10. A ☐ B ☐ C ☐ D ☒
Most high-power public address systems in outdoor installations use
(A) transformerless tube amplifiers. (B) sound column speakers. (C) many low-powered baffle-mounted speakers. (D) directional horn speakers.

HI-FI STEREO SYSTEMS

7530

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This integrated hi-fi stereo system includes a tape recorder, AM-FM/stereo tuner as well as a record changer.

Courtesy General Electric Co.
Audio Products Dept.

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A hard fall should mean a high bounce if one
is made of the right material.
—The Youngstown Bulletin

HI-FI STEREO SYSTEMS

What is high fidelity? The term **HIGH FIDELITY,** or hi-fi, has been so loosely used that now it is applied to almost all types of home-entertainment music reproducing systems, ranging from low cost portable record players to the highest quality component systems. In the strictest sense of the word, hi-fi refers to a sound system that FAITHFULLY reproduces the original sound. A hi-fi system should not add any additional sounds, nor in any way distract from, or "color," the reproduced sound.

In the early days of sound systems, distortion was quite high. As the state of the art advanced, better systems were produced, and very low distortion levels were achieved. Nevertheless, something was missing. The reproduced signal did not sound the same as a live performance. Although the full range of music tones could be reproduced, a sound system output signal still lacked many qualities that are evident at a live music performance. The problem was that at a live performance, sound waves reach our ears from all directions. In the hi-fi music system, the sound waves come from one point, the speaker system. The complex sound wave patterns at a live performance were not reproduced in our home. To overcome the limitations of a MONAURAL, or single channel sound system, the STEREOPHONIC sound system was developed. In a stereophonic sound system, two or more sound channels are provided. The sound wave patterns produced by two or more separate speaker systems produce a complex sound wave pattern similar to that at a live performance. Although the pattern is not quite the same, the effect is pleasing and the "illusion" of presence is a marked improvement over the monaural system.

To provide the best stereo effect, the system's speakers must be properly arranged in the listening room. Figure 1 shows the most desirable arrangement when separate speaker systems are employed. The speakers must be far enough apart to provide adequate separation between the signals of the sound channels. However, too much separation is as bad as not enough. The best listening area is shown in the shaded portion of the figure. It is usually necessary to experiment with speaker placement to obtain the best stereo effect in a given room.

When both speaker systems are in the same cabinet, as in some console systems, the speakers are often angled outward to provide separation. The room acoustics also have an effect on the stereo illusion. A room with bare walls and floors has more reflections than a room with heavy drapes, stuffed furniture and thick carpeting. Most recordings are produced to sound best in rooms that are furnished in a manner that is between these two extremes.

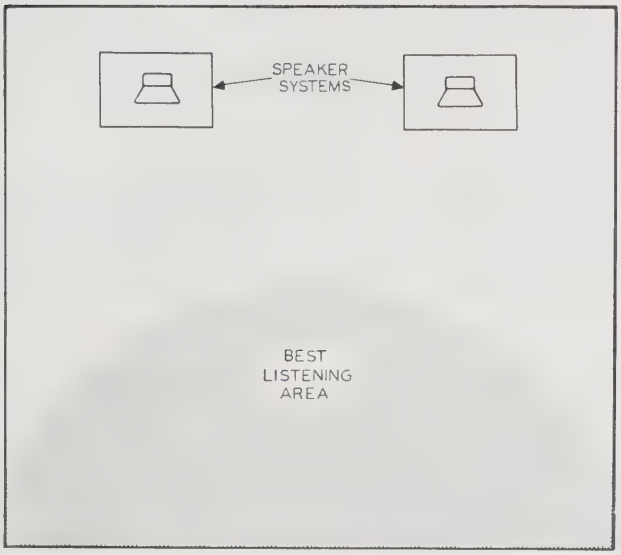


Figure 1

MUSIC SYSTEMS

There are many ways in which a music system can be set up. Two general arrangements are normally found in home-entertainment music systems. One type is a COMPONENT SYSTEM. In a component system, separate units, often in different cabinets and from different manufacturers, make up the system. Figure 2 is a block diagram of a typical component system. Three separate sound sources are provided: a turntable or changer, an AM-FM/stereo tuner and a tape deck. Each source has two outputs, left (L) and right (R), to provide a two channel stereo system.

The desired input unit is selected by the input selector switch of the Preamplifier Control Unit. The preamplifier contains the tone control

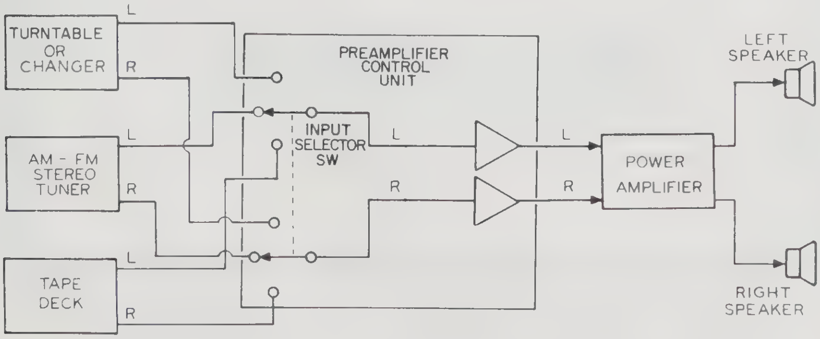


Figure 2

circuits and compensating circuits necessary to provide the proper frequency response from various signal sources. Level and balance controls are also included to control the output sound level and balance.

Following the preamplifier, the power amplifier steps up the signals to a power level high enough to drive the speakers. Although only one speaker is shown for each channel, most systems employ several speakers in each channel for improved frequency response.

During the early days of hi-fi and stereo, most people felt that only component systems gave high-quality sound reproduction. Of course, the component systems were more expensive and as a result were generally better. Today, however, many INTEGRATED systems are comparable in quality to good component systems. In an integrated system, most or all of the components are housed in the same cabinet, often with most of the circuitry on the same chassis.

From a servicing standpoint, the component system is usually easier to troubleshoot. All of the units are separate, which makes it easier to isolate the defective unit. With an integrated system, this may not be as easy to do since the units may share the same power supply and other circuits.

Many systems are a compromise between the two system types. For example, a tuner, preamplifier and power amplifier may be combined in the same unit, or a preamplifier and power amplifier may be combined to form one unit. The speakers and additional input units are separate.

HI-FI SYSTEM SPECIFICATIONS

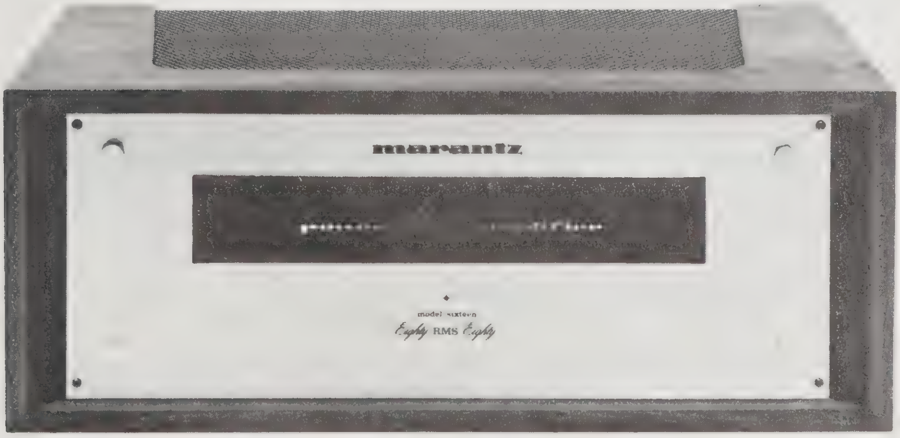
Service technicians, as well as purchasers and users of hi-fi/stereo equipment, are often confronted with an impressive array of equipment specifications. An understanding of these specifications is important because a service technician may have to "bring a unit up to specifications." The specifications are also important to many purchasers, as they use the specifications to help them select the equipment that they purchase.

Over the years, many procedures have been used to check the performance of hi-fi equipment. Confusion has sometimes occurred because different manufacturers have employed different procedures for the same tests, often making comparisons impossible. To eliminate this problem, the Institute of High Fidelity, **IHF**, was formed. A set of test procedures was drawn up and is now in general use by hi-fi equipment manufacturers.

Amplifier Specifications

The most basic specification that can be applied to an amplifier is power output. A simple stating of power output alone, however, is almost meaningless. For a rating of output power to be worthwhile, the distortion obtained at the rated power, the load impedance and test frequency used must also be indicated. The IHF specifies that the test frequency for a test of maximum power output be 1000 Hz, and the power rating be for sinewave, power output. This is called **IHF POWER.** Thus, an amplifier may be specified as having 60 watts IHF per channel, at less than 0.5 percent total harmonic distortion. The test frequency is understood to be 1000 Hz and the power obtained for a sinewave input signal. A more meaningful test of power output is called **RMS POWER** output. In this test, both amplifier channels are driven simultaneously, and the amplifier's own power supply must be used. For this test, the input signal is a continuous 1000-Hz sinewave, and the load impedance also must be indicated in the results.

An even more complete picture of the amplifier characteristics is given by specifying the power response obtained over the amplifier's entire frequency range. A stereo amplifier may be rated at 60 watts rms per channel, ±0.5 dB, 5 to 100,000 Hz, with total harmonic distortion under 0.5 percent and intermodulation distortion under 0.5 percent. This amplifier can therefore deliver 60 watts rms (continuous) output ±0.5 dB (±7.5 watts) per channel. The total harmonic distortion indicates the additional signal frequency components generated by the amplifier when single signal frequencies are applied. The intermodulation distortion indicates the additional signal frequency components generated when two separate signal frequencies are



This solid-state stereo amplifier can deliver 80 watts of sinewave power per channel. The response is within .2 dB, 10 to 60,000 Hz.

Courtesy Marantz Co., Inc.

applied. The specifications of many of the amplifiers designed for professional use include this information. The specifications for units designed for normal home-entertainment applications often contain only results obtained with the IHF method of testing.

Because of inconsistencies in measuring techniques, the IHF power output specifications for an amplifier may vary from 20% to 50% higher than the amplifier's rms power output specification. Compared to the output obtained for an 8-ohm load, most modern solid-state stereo amplifiers provide about 20% to 25% less output power into a 16-ohm load, and about 25% more output power into a 4-ohm load.

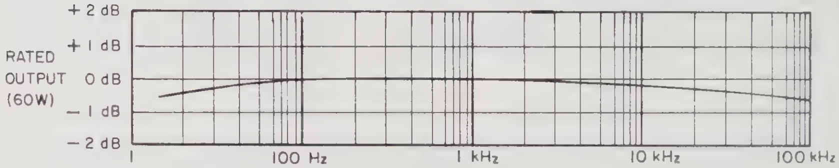


Figure 3

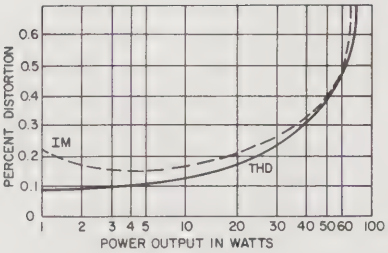


Figure 4

Although the figures given previously specify the amplifier response, they are sometimes difficult to understand and often do not give a real "picture" of the amplifier's performance. A more meaningful method is to put the specifications in the form of a graph. Figure 3 shows the frequency response at maximum power output, and Figure 4 shows the total harmonic distortion and intermodulation distortion for the same amplifier at various power levels. The graphs show any irregularities in the response.

Any appreciable IM distortion is immediately apparent to most listeners because of the harsh, edgy quality it gives to the reproduced music. Considerably greater amounts of harmonic distortion will usually remain unnoticed because of their harmonic relationship to the original sounds. However, any amount of harmonic distortion that is present will almost always be accompanied by a greater amount of IM distortion, which indicates that it is quite important to keep the quantity of harmonic distortion as small as possible.

Since music is not continuous, but is instead a series of changing tones, most amplifiers can produce greater maximum power output with music than when subjected to a continuous tone. This is because the amplifier's power supply is not strained during the short power bursts caused by music signals. As a result, some amplifiers are also given a **MUSIC POWER** rating. Figure 5 shows the difference between a continuous sinewave and one cycle of a music signal. With a continuous sinewave, as in Figure 5A, the average power is .637 of the peak power. However, with a complex music waveform as in Figure 5B, the average power is less than the average power for a sinewave with the same peak power value. Some amplifiers with lower quality power supplies can deliver considerably more peak music power than peak sinewave power.

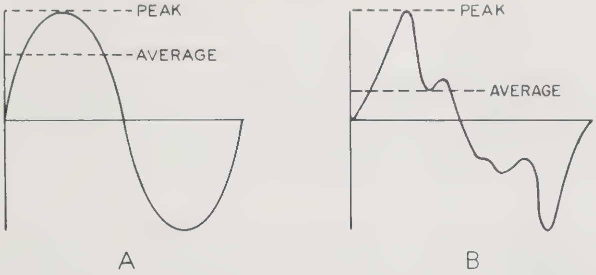


Figure 5

There are several other specifications which are often given for amplifiers. One of these is **SENSITIVITY.** This specification merely states the input signal level required to develop the amplifier's full rated output. For example, an integrated amplifier containing a preamplifier and control unit may require an input signal of 5 millivolts to produce its rated power output.

Another amplifier specification is **HUM AND NOISE.** This specification indicates the amount of hum (power supply ripple) and other internal noise originating in the amplifier that is present at the amplifier output. This specification is generally given in dB in reference to the rated output. A typical spec of this nature would be: Hum and noise −78 dB below 60 watts output.

A useful specification, generally in the form of a graph, is tone control action. Figure 6 shows such a graph. The graph shows the maximum boost and attenuation characteristics of the bass and treble controls. There are many other specifications that are given for amplifiers, but the ones presented in this lesson are some of the most important ones.

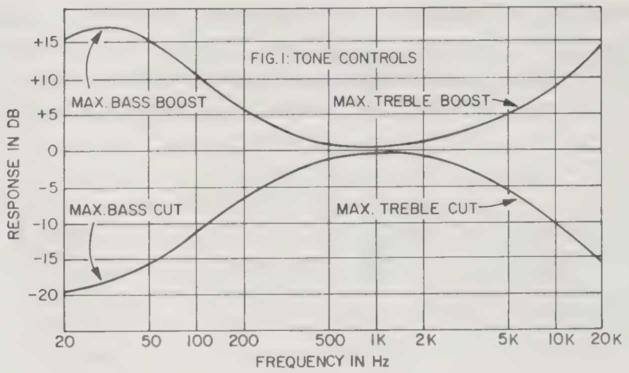


Figure 6

FM Tuner Specifications

As with amplifiers, there are a number of specifications that are applied to FM tuners. The IHF has also set up specification standards for tuners. Probably the most frequently published specification is **IHF SENSITIVITY.** This may also be considered the least usable sensitivity for an FM tuner. It indicates the signal strength at the antenna terminals, in microvolts, which causes the sum of noise and distortion of a signal to be no greater than 3% of the loudest portion of the program's material being transmitted. Distortion of 3% is equal to 30 dB of quieting. For a tuner with an IHF sensitivity specification of 1.25 μV, this means that a 1.25 μV signal is required at the antenna terminals of the tuner to reduce the noise and distortion content of the signal 3%. The LOWER THE ANTENNA VOLTAGE REQUIRED for a 30-dB noise and distortion level (30 dB quieting), the MORE SENSITIVE the tuner. However, 30 dB of quieting does not provide very satisfactory listening, as this amount of background noise is quite noticeable. At least 40 dB of quieting is required for an acceptably low background noise level, and most modern FM tuners have enough sensitivity to obtain 40 dB of quieting with a signal strength of about 10 μV for a monophonic signal. Because of the system selected for stereophonic FM broadcasting, most tuners require from 2 to 10 times as much input for a stereo signal to achieve the same amount of quieting.

EFG

Another important tuner specification is **SIGNAL-TO-NOISE (S/N) RATIO.** This specification indicates the amount of background noise present. As the signal level increases, the background noise decreases until the ultimate quieting of the tuner is reached. The residual noise left may be wide band rushing noise, hum or a combination of both. Typical signal-to-noise ratios run from 50 to 70 dB in mono, and 40 to 55 dB in stereo. The higher the figure, the better the tuner.

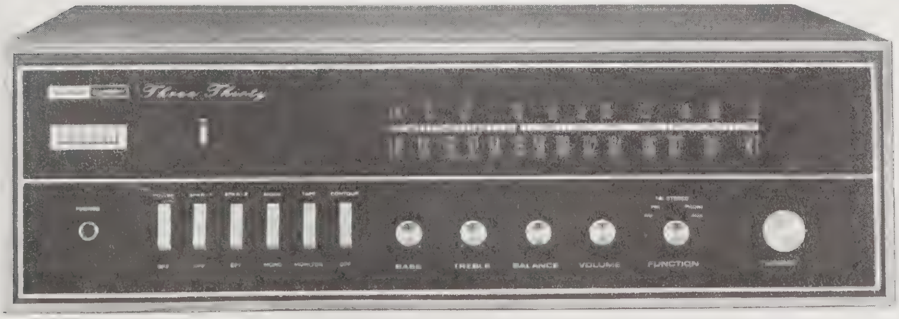
As signal level is increased, the distortion in the tuner decreases until it reaches a minimum point. The minimum distortion is also given as a specification called Total Harmonic Distortion, THD. The THD can be expressed as a percentage or in dB. A good tuner will have a THD that gets down to about 0.2% in mono, and remains less than 1.0% in stereo.

Another specification is **DRIFT.** This specification indicates the amount of tuner drift in kHz that occurs after a period of two hours. The automatic frequency control (afc) circuits in the tuner keep drift to a negligible amount so that retuning is not necessary. Many modern tuners are so stable in their operation that no afc is required, as drift is negligible.

Most modern FM tuners have frequency response that covers the range of about 30 Hz to 15 kHz. Wider frequency response is not necessary, as the FM broadcast stations can only transmit audio signal frequencies from about 30 to 15 kHz. Most stereo transmissions contain almost no signal information above 12 kHz because of FM channel bandwidth restrictions.

The ability of a tuner to separate two channels on the same frequency is referred to as **CAPTURE RATIO.** This specification indicates in dB how much difference is required in signal strength between two signals on the same frequency for the stronger signal to suppress the weaker signal by 30 dB. The lower the capture ratio, expressed in dB, the better the tuner. A high-quality modern tuner may have a capture ratio of about 1.5 dB.

A good capture ratio allows a tuner to reject reflected versions of a desired signal. These reflected signals, called multipath distortion, are common in urban areas, where tall buildings can cause a desired signal to arrive at



The AM-FM/stereo receiver shown above includes both a preamplifier/control unit as well as a power amplifier. The IHF sensitivity is 2.7 μV.

Courtesy Harmon Kardon Inc.

a receiver's antenna from different directions. It is the slight delay of the reflected signals, mixing with the original signal, that causes distortion.

Another important tuner specification is **SELECTIVITY.** FM broadcast station channels are 200 kHz apart. To prevent adjacent channel interferences, the FCC usually spaces the stations in a given area two channels, or 400 kHz, apart. However, it may be possible to receive two stations on adjacent channels.

The extent that an alternate channel signal is rejected, in comparison to the desired signal, is indicated in dB. Selectivity of 70 to 90 dB is often attained.

There are several specifications for stereo FM tuners that indicate the unit's quality of performance. STEREO FM SEPARATION indicates how much left channel information appears in the right channel, and vice versa. Most manufacturers indicate the separation at 1000 Hz. However, a more realistic approach would be to indicate the separation across the entire audio band. Broadcast stations are required to maintain at least 40 dB separation across the audio band, but many tuners can only provide this much separation at 1000 Hz.

In general, stereo FM reception requires greater signal strength than monaural FM reception does for an equally noise-free signal. Thus, the Stereo FM sensitivity is lower than the monaural FM sensitivity.

Stereo Total Harmonic Distortion may also be higher than that for monaural operation. Additional circuitry is required for stereo operation which may introduce additional distortion.

If attenuation of the 19-kHz pilot, the 38-kHz subcarrier, and any 67-kHz SCA signals that are present is not sufficient, increased distortion may result. Mixing between these frequencies and audio signal tones can cause large amounts of IM distortion.

FOUR CHANNEL SOUND

Recent developments in the field of sound reproduction have resulted in increased realism in the recorded signal. When an orchestra is recorded in a large hall, some of the reflected sound waves that strike the hall's ceiling and walls arrive back at the microphones. The relationship between these

The following Practice Exercise questions cover the subjects which you have just studied. They are:

MUSIC SYSTEMS

HI-FI SYSTEM SPECIFICATIONS

AMPLIFIER SPECIFICATIONS

FM TUNER SPECIFICATIONS

1. What is meant by the term "high fidelity?"

2. A stereo system produces the exact sound wave pattern that occurred when the music was recorded. True or False?

3. The best stereo effect is obtained when the speakers are placed as far apart as possible. True or False?

4. What is a component system?

5. The system of Figure 2 has _____ channels.

6. What is an integrated system?

7. A separate component system is often easier to service than an integrated system. True or False?

8. What is the difference between harmonic and intermodulation distortion?

9. The reference frequency employed for IHF frequency response measurements is (a) 100 Hz, (b) 1 kHz, (c) 10 kHz.

10. If an amplifier can deliver considerably more peak music power than sinewave power, what section of the amplifier is at fault?

11. What is indicated by the sensitivity specification of an amplifier?

12. An amplifier with a hum and noise specification of −70 dB is better than one with a spec of −60 dB. True or False?

13. The IHF sensitivity is the signal level in μV at the antenna necessary to place the noise and distortion ________ ________ below the loudest program material.

14. The amount of background noise present in an FM tuner at ultimate quieting is specified as the (a) capture ratio, (b) S/N ratio, (c) sensitivity.

15. What is the purpose of the afc circuit in an FM tuner?

16. What is capture ratio?

17. What is selectivity?

reflected sound waves and the direct sound of the orchestra represents a quantity that imparts characteristics of the room in which the recording is made. This "hall sound," or "ambiance," as it is sometimes called, provides greater realism to the reproduced sound when it is included in the recording. Most of the hall sound arrives at the left and right channel microphones out-of-phase in a manner that causes cancellation when the recording is played back in normal two channel stereo.

If a suitable decoding circuit is used to recapture the ambiance signal, it can be fed to a separate speaker. The sound from the regular left and right channel speakers is then combined in the listening room with the sound from the ambiance signal speaker. The amount of added realism provided by this technique depends on many variable factors, the most important being microphone placement. Greater control is obtained when microphones are added specifically for recording the ambiance signals.

At least two of these extra microphones are usually used, and they are placed near the left and right rear corners of the recording hall. The outputs from these microphones are then used for TWO ambiance, or rear channel, signals.

Several methods have been selected for incorporating these rear channel signals into recordings. Three methods commonly used for phonograph records include one multiplex system and two different matrix systems.

In the multiplex, or "discrete," system, signal information that represents the front channels PLUS the rear channels is cut directly into the record grooves, and signal information that represents the front channels MINUS the rear channels is incorporated as frequency and phase modulations of a 30-kHz carrier signal that is inscribed in the grooves.

Pickup cartridges with relatively flat response to 45 kHz are required to extract these complex signals from the record grooves. Several cartridges with this capability are presently available. The two output signals of the cartridge go to an appropriate discriminator circuit in a unit whose four outputs represent the signals of the left and right front and rear channels for playback through four separate speaker systems. This arrangement is called the CD-4 system.

One of the matrix arrangements is called the SQ system. The other one is referred to as either QS or RM (Regular Matrix). In the matrix systems, information representing channel sum and difference and phase difference signals is inscribed directly in the record grooves so that an ordinary pickup cartridge may be used for playback. The two output signals of the cartridge go to appropriate dematrixing networks to obtain the four signals carried in the record grooves.

Truly discrete four channel recordings are available on reel-to-reel and 8-track cartridge prerecorded tapes.

Four channel sound permits the use of gimmick-type recordings. Instruments or singers may be made to seem to jump from corner to corner of the listening room, or hover in the air in the middle of the room. Trains, planes and motorcycles can be made to seem to roar about the room.

TROUBLESHOOTING HI-FI STEREO SYSTEMS

The first step in troubleshooting a music system is to isolate the defective section or unit. Figure 7 shows an expanded block diagram of the high-fidelity stereo system shown earlier in Figure 2. This system provides stereo reproduction from any of three input devices. The switching system connects the left and right channel signals of the selected source to the left and right channel amplifiers.

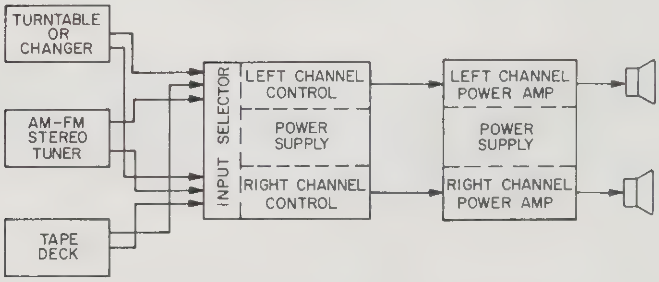


Figure 7

Not all systems contain all of the components included in Figure 7. For instance, many systems include either a tape player or a phonograph, but not both. In a great many units, the preamplifiers for switching and control of the various input channels are all combined into the same unit as the two power amplifiers. Often the tuner is also included in this same basic unit, as in a stereo receiver.

Trouble in the Speaker System

Suppose trouble develops in one of the speaker systems. This does not necessarily mean the speaker itself is defective. The trouble may be in an attenuator used to control the volume at some remote speaker, or it may be in the crossover network used to split the signal for a bass speaker and a high-frequency speaker. Trouble at any of these points can result in either a complete lack of output, badly distorted output, or loss of either high- or low-frequency response.

Trouble in the speaker system of one stereo channel generally does not affect the output from the other channel. If there is more than one set of speakers, as in the case of systems with outputs available either in the living room or recreation room, speaker troubles may be confined to one of the sets of speakers. The trouble may disappear when you switch to another set of speakers. This is a clear indication that the trouble is in the speaker system. If it were in the amplifier section, switching speakers would have no effect. Similar checks can be made by interchanging the right and left speakers at the output of a stereo amplifier.

After the components of a stereo system have been connected together, check for correct phasing of the speakers. If playback of a music selection makes musical instruments or a singer seem to move rapidly back and forth across the listening room, or if it is difficult to pinpoint the apparent location of a performer, the speakers are probably out-of-phase. Reversing the connections to one speaker should provide the proper stereo image, and also increase the system's bass response.

Trouble in the Amplifier

If a malfunction results in no sound from either speaker, several checks can be made that will usually pinpoint the source of the trouble rather quickly. If ac line power is present, the line cord is not open, no fuses are blown, the power switch isn't open and no overload protection circuitry has disabled the power amplifier; the trouble probably is in the amplifier power supply. In the separate component systems of Figure 7, this means the power supply of the power amplifier. In an integrated amplifier or a receiver, it would be the power supply of the entire unit.

A problem that results in no sound from one channel indicates a malfunction at some point in the signal path for that channel only. If changing a Mono-Stereo switch to the position labeled Mono results in sound output from the malfunctioning channel, the problem source is at a point prior to this Mono-Stereo switch. Changing the selector switch to a different program source will allow further pinpointing of this malfunction's origin. If there is no output from one channel, regardless of the program source selected, the problem originates at some point after the selector switch.

When trouble occurs in either the right or left channel amplifier in a stereo system, only that channel is affected. To be certain that the trouble does not originate after the amplifier, interchange the speaker leads. Troubles in the amplifiers may be loss of gain, loss of frequency response, audible noise or distortion, or no output at all.

When the trouble is in the amplifier, it usually affects all inputs similarly. If there is low output when a tuner provides the input, there will also be low gain when a phonograph is used as the input. If the difficulty is associated with the input device, it will only affect one of the inputs. If the trouble is in the preamplifier/control section, it may only affect performance for certain selector switch settings, or it may prevent proper operation regardless of switch positions.

Input Device Troubles

When trouble occurs in an input device, it usually appears only when the defective input device is in use. For example, a malfunctioning tuner would not normally affect the performance of a tape deck or turntable. However, in some systems the tuner and amplifiers share the same power supply so that troubles in the tuner might render the whole system inoperative.

Troubles in the input devices may or may not affect both channels. A stereo tape player, for instance, would affect both channels if it were running at the wrong speed or not tracking properly (misaligned playback head). Conversely, it might generate noise on one channel and not the other, or it might cause complete loss of the signal on only one channel.

In a stereo tuner, any trouble occurring before the detector affects both channels. Difficulties in the audio section of the tuner may affect only one channel.

Trouble in the turntable or changer will affect both channels when there is mechanical trouble such as incorrect speed, wow, rumble, etc. Trouble in the pickup arm or cables might affect only one channel.

Servicing of turntables, like the one shown above, usually involves cleaning and minor mechanical adjustments.
Courtesy United Audio Products, Inc.

Your best clue in localizing troubles in the input devices is the difference in behavior between different inputs. If the output from the turntable or changer is all right, but you are unable to pick up stations when you switch to the FM tuner, then the amplifiers and speakers are not at fault. You may have to investigate the switching circuits in the preamplifier-control section, but there will be some point early in the amplifier circuitry that is common to the FM tuner and the turntable or changer; and you know that from this point on the system is working properly.

Distortion

Assume that a system malfunction is distortion of signals in the left channel only. This automatically eliminates half the system as a problem source.

Check the left speaker system by reversing the connections so that the left speaker is connected to the right amplifier. If the trouble is in the speaker, the distortion will still be heard from the same speaker, but if the trouble is in the amplifier, the distortion will be coming from the speaker now connected to the output of the left amplifier.

If the output of the left channel speaker is distorted even after the speakers are interchanged, the trouble is probably in the amplifier. The best way to locate the origin of distortion in any amplifier is by using an oscilloscope and observing the signal at certain points in the amplifier.

For such tests, the normal input device is not a satisfactory signal source. Use an audio generator with a good sinewave or square wave output. Feed the signal into the input of the amplifier and adjust the signal level so that the first amplifier stage is not overdriven. Unless you know that the distortion occurs only on high- or low-frequency signals, select some midrange frequency and adjust the horizontal sweep in the oscilloscope for a stationary pattern with several cycles of the audio signal displayed on the screen.

If there is serious distortion anywhere in the amplifier, you should be able to locate the defective stage through waveform observation. In most stages, a phase reversal takes place, but there should be no evidence of either flattening of peaks or change in the slope of any waveform trace.

When a stage is found where the output signal is not a good reproduction of the input signal, voltage measurements in that stage may pinpoint the trouble source.

Accurate voltage measurements are very important in modern amplifier direct-coupled stages, as only slight deviation from a proper voltage can, at some circuit points, cause very high distortion levels.

Hum

Continuous low-frequency noise, called hum or buzz, might be heard from a hi-fi stereo system. Some noise of this nature is inherent in almost any system, but careful selection and placement of components will keep the noise level nearly inaudible in a properly operating system. If hum or buzz of 120 or 180 Hz is loud enough to be objectionable, it is probably caused by inadequate power supply filtering or as a result of physical vibration (buzzing) of the power transformer core laminations.

An objectionably loud lower frequency hum of 60 Hz will most often accompany the output of a low-level signal source, such as a phono cartridge or tape head. This type of hum is usually caused by inadequate shielding or grounding of the record player or tape deck, or by stray field pickup from the cartridge, tape head, or the leads that run between these transducers and their preamplifiers. Audible 60-Hz hum may also be the result of open ground leads or ground loops caused by multiple ground paths, or poor ground connections.

To decrease residual hum to its lowest level, reverse the wall plugs of the line cords of the system's components until the combination that produces the least hum is determined. In extreme situations, run a separate ground lead from each component to the control unit, and from the control unit to a good ground, such as a cold water pipe or radiator. DO NOT attempt this arrangement with any line-operated equipment (ac-dc sets), and be certain to check for electrical shock hazards in any arrangement of this type.

Troubleshooting Loudspeaker Systems

As we have already pointed out, some of the faults in high-fidelity systems will be traced to defects in the speaker system.

Troubles in the speakers such as loose or torn speaker cones cause serious distortion. In a good hi-fi system, no attempt should be made to repair a damaged speaker. The best solution is to return it to the manufacturer for repair.

The speaker arrangement in many home installations includes speakers in more than one room. Usually, such installations provide for switching various combinations of speakers on or off. Most modern high-fidelity amplifiers deliver more power as the load impedance decreases. Therefore, remote or extra speakers may be connected in parallel across the main speakers.

HOWEVER, A LOAD IMPEDANCE OF LESS THAN 4 OHMS MAY OVERLOAD AN AMPLIFIER.

Be certain that the dc resistance of the speaker load is not less than 4 ohms for each channel, with all speakers connected to the amplifier.

Figure 8 shows the L pad arrangement usually used when individual speaker volume control is desired. The sections of the control are designed so that the signal to the speaker may be decreased, but the total load resistance on the amplifier remains virtually constant for any setting of the control.

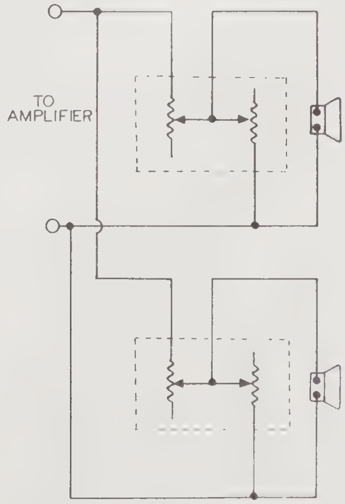


Figure 8

The above photo shows a speaker designed to reproduce low frequencies.

Courtesy T. R. Bozak Mfg. Co.

In such a system, if the front section of the control opens, there will be no output at any setting below the open point. If the back section opens, the control loses most of its effect. It will reduce the output only a little at its lowest setting. A more common complaint will be noise when the control is turned. A control cleaner may be used or it may be necessary to replace the control.

COMPONENT MATCHING AND ACCESSORIES

The extremely low distortion levels that are achieved with modern high-fidelity components can be maintained only with proper impedance and voltage levels between the system interconnections. The various system input circuits must be capable of properly amplifying the weakest input signals and must handle, without overload, the strongest input signals that they are likely to receive. The input circuit input impedances must also be correct for the devices to which they are connected if proper frequency response is to be retained.

Phono input impedance has been standardized at 47K ohms. High-level signal input circuit impedance should usually be at least 100K ohms, except for the input to a power amplifier. The input impedance of a separate power amplifier might be as low as 20K ohms, and it must therefore be ascertained that the control unit which drives the power amplifier is intended for use with that low a load impedance.

The power capability of the amplifier selected must be sufficient for its intended usage. Most "bookshelf" speaker systems are quite low in efficiency (1% is typical). When these speakers are used in large rooms that contain considerable sound-absorbing furniture (heavy drapes, rugs, etc.), high-powered amplifiers are required to obtain loud music levels.

The current popularity of hi-fi stereo systems has resulted in the availability of many types of accessory units. Most of these accessories provide greater convenience and versatility of control of system operation.

Noise reduction units, connected between system components which are determined by the unit's function, are quite common. A popular type of noise reduction circuit, called the Dolby type B, is usually connected between a tape recorder and a control unit. The signal to the recorder is processed by the Dolby unit in such a way that, during recording of soft, or low-level, music passages, the higher frequency signal level is increased by an amount that is inversely proportional to the original signal amplitude. During playback, the Dolby unit decreases these same signals in such a way that the original program balance is restored. This process improves the signal-to-noise ratio of the higher frequency signals by as much as 10 dB. Because most noise energy of a recording is at the higher frequencies, the effect of this action is to increase the entire signal-to-noise ratio of the signal by 10 dB.

Adapter units for four channel, or "quadraphonic," sound are often employed. Passive units, designed to obtain ambiance signals from stereo records, are attached to the speaker connections, and the rear channel speakers are then connected to the outputs of the adapters.

Units for CD-4, SQ or QS (RM) signals are connected between the control and power amp sections of the system. Their rear channel signals go to separate amplifier sections used to drive the rear channel speakers.

Another type of accessory is a graphic equalizer, a multiple-range tone control that separates the audio-frequency range into as many as twenty-four different segments whose amplitudes may be independently boosted or attenuated.

Certain types of visual display units are available that are designed to indicate specific functions. Some are used to show signal distribution in the four channels, some give a visual display of FM multipath, and still others have different uses.

SUMMARY

The essential components of a home high-fidelity music system are signal source, amplifier and speaker system. When the system is intended for stereo reproduction, the amplifier and speaker system must include two separate channels.

Many purchasers select their music system components on the basis of published specifications. It is therefore important to know the significance of each specification.

A recent innovation is four channel, or "quadraphonic," sound, which makes use of four independent sound channels. It can increase the realism of the recorded sound by supplying some of the hall sound, or "ambiance," of the room in which the recording was made.

In servicing any equipment, the first requirement is to determine which basic unit is at fault. If both channels of a stereo system are similarly affected, a problem source can be in the input unit, in the power supply, or it may be a trouble in one channel that causes the power supply to operate improperly. If only one channel is affected, further checks should include interchanging speakers and input units. If the trouble changes channels when this is done, the problem source is prior to the point at which the signal switched channels. Using either a meter or an oscilloscope to compare voltage measurements and signals from an audio generator between the good and

The following Practice Exercise questions cover the subjects which you have just studied. They are:

- FOUR CHANNEL SOUND
- TROUBLESHOOTING HI-FI STEREO SYSTEMS
  - TROUBLE IN THE SPEAKER SYSTEM
  - TROUBLE IN THE AMPLIFIER
  - INPUT DEVICE TROUBLES
  - DISTORTION
  - TROUBLESHOOTING LOUDSPEAKER SYSTEMS
- COMPONENT MATCHING AND ACCESSORIES

18. The CD-4 "discrete" four channel system uses a supersonic carrier frequency for some of the encoded signal information. True or False?

19. Rear channel signals may be obtained from ordinary stereo records. True or False?

20. List the essential parts of a hi-fi system.

21. When it is suspected that trouble in a stereo system is the result of a defective speaker in one channel, what simple test can be made to confirm this?

22. The right channel signal of a stereo system is distorted but the left channel signal is normal. When the speaker systems are switched, the trouble remains in the right channel. The trouble is probably in the (a) right channel amplifier, (b) right channel speaker system, (c) left channel amplifier, (d) left channel speaker system.

23. When the trouble occurs in a power supply that is common to both channels, what is the likely result?

24. When the record player in a stereo system is selected for playback, both channels work normally. However, when the FM stereo tuner is selected, both channels are inoperative. What parts of the system would you check?

25. If there is no output from a stereo system, what checks would be made to determine the unit at fault?

26. What instrument is useful in locating a stage that is producing distortion?

27. In comparing oscilloscope patterns of stage input and output signals in a hi-fi amplifier, which of the following is normal? (a) Clipping. (b) Distortion. (c) 180° phase shift.

28. An equalizer is used to provide greater control over frequency contouring of a hi-fi system signal. True or False?

29. A popular noise reduction system component is the ______________ __________ ______.

defective channels is a good way to locate the trouble when one amplifier in a stereo pair is defective.

To retain the quality that modern music reproduction systems are capable of, it is important that all components be properly matched for correct signal levels and impedance.

IMPORTANT DEFINITIONS

CAPTURE RATIO—An indication of the ability of a tuner to reject an undesired signal on the same channel as the desired signal.

DRIFT—An indication of the amount that a tuner drifts in kHz in a 2-hour period.

HIGH FIDELITY—The name given to a sound reproducing system that reproduces the sound of a recording with a minimum of distortion.

HUM AND NOISE—The amount of hum (power supply ripple) and other internal noise appearing at the amplifier output.

IHF—Institute of High Fidelity—An organization set up to standardize hi-fi system specifications.

IHF POWER—A somewhat arbitrary specification for an amplifier's maximum power output at 1000 Hz.

IHF SENSITIVITY—The signal strength in μV at the antenna terminals of a tuner necessary to reduce the output in which sum of noise and distortion is 3% (30 dB) of the maximum output. Also called the least usable sensitivity.

MUSIC POWER—An amplifier power rating taking into account the fact that music is not continuous, but consists of short bursts of complex tone structures.

RMS POWER—An indication of the continuous sinewave output power of one channel of an amplifier with all channels driven, while using the amplifier's own power supply. The input signal is a 1000 Hz sinewave of constant amplitude, and the amplifier's load impedance must be indicated along with the output power obtained.

SELECTIVITY—An indication of the ability of a tuner to reject adjacent channel signals.

SENSITIVITY—With respect to amplifiers, the input signal level required to produce maximum power output.

SIGNAL-TO-NOISE (S/N) RATIO—An indication of the amount of background noise present at the output of a tuner when the signal level is sufficient to produce ultimate quieting.

PRACTICE EXERCISE SOLUTIONS

1. The term "high fidelity" refers to a sound system that faithfully reproduces the original sound without adding any additional sounds or distortion.

2. False—The sound wave pattern produced by the stereo system is not exactly the same as the original, but is similar.

3. False—The speakers should be separated but not too far apart. The separation must be experimented with to obtain the best results in a given room.

4. A component system is made up of independent units.

5. two

6. An integrated system is one in which the electronic sections of a music system are housed in the same cabinet and often are built on the same chassis.

7. True

8. Harmonic distortion refers to the amount of additional signal frequencies generated by the amplifier when a single signal frequency is applied to the input. Intermodulation distortion refers to the additional signal frequencies generated when two separate input frequencies modulate each other in the amplifier.

9. (b) 1 kHz.

10. The power supply.

11. The sensitivity specification indicates the input signal level required to produce maximum rated output.

12. True

13. 30 dB

14. (b) S/N ratio.

15. The afc circuit reduces drift.

16. Capture ratio specifies the ability of the tuner to reject a weaker undesired signal on the same channel as the desired signal.

17. Selectivity is the ability of a tuner to reject adjacent channel interference.

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7530A
EXAMINATION CHECK SHEET

7530A

1. D - A MUSIC SYSTEM HAVING TWO OR MORE SEPARATE CHANNELS IS A - - STEREOPHONIC SYSTEM.
A monaural system has one channel and a stereo system has two or more separate channels.

2. C - A MUSIC SYSTEM EMPLOYING A SEPARATE TUNER, TURNTABLE, AMPLIFIER AND SPEAKER SYSTEM IS CALLED - - A COMPONENT SYSTEM.
A component system employs separate units and an integrated system has common units.

3. D - THE IHF POWER OUTPUT SPECIFICATION IS GIVEN AT A TEST FREQUENCY OF - - 1 kHz.
The IHF specification is for sinewave power at 1 kHz.

4. D - WITH RESPECT TO AMPLIFIER POWER RATINGS, - - MUSIC POWER RATINGS ARE OFTEN HIGHER THAN SINEWAVE POWER RATINGS.
Due to the pulse characteristics of music, higher peak power can be achieved on music as compared to a continuous sinewave signal.

5. B - THE ABILITY OF A TUNER TO REJECT AN UNDESIRED SIGNAL ON THE SAME CHANNEL IS CALLED - - CAPTURE RATIO.
The lower the capture ratio in dB, the better the tuner.

6. D - IN FOUR CHANNEL RECORDINGS, THE AMBIANCE SIGNAL REPRESENTS - - INFORMATION PERTAINING TO SOUND REFLECTIONS IN THE RECORDING STUDIO.
Four channel recordings are also used to achieve special effects, such as making a sound move around the room from speaker to speaker.

7. D - THE QUICKEST WAY TO CHECK SPEAKER SYSTEMS IN A STEREO SYSTEM IS TO - - INTERCHANGE THE SPEAKERS BETWEEN THE CHANNELS.
If the trouble changes channels with the speaker, the trouble source is in the speaker. If not, the amplifier is defective in that channel.

8. C - IF ONE CHANNEL OF A STEREO SYSTEM IS INCORRECTLY PHASED, - - THE STEREO IMAGE WILL BE INDISTINCT, AND BASS WILL SOUND WEAK.
Out-of-phase high-frequency tones will seem to jump back and forth between speakers, and low-frequency tones, which are essentially in phase in a normal signal, will be weak due to cancellation.

9. A - A LOUD HUM HEARD FROM ONE CHANNEL WHEN LISTENING TO RECORDS INDICATES THAT - - THE GROUND LEAD FOR THAT CHANNEL'S SIGNAL CABLE IS OPEN.
An open ground lead always increases hum level.

10. B - A MODERN SOLID-STATE AMPLIFIER WILL DELIVER THE MOST OUTPUT POWER TO - - A 4-OHM LOAD.
A load of 4 ohms is usually closest to a perfect match for the output of a modern high-quality transistorized amplifier.

PRACTICE EXERCISE SOLUTIONS (Continued)

18. True

19. True

20. The essential parts are the input device or devices, preamplifier and control section, power amplifier and speaker system.

21. Switch the speakers from one channel to the other. If the distorted signal appears in the other channel, the speaker is defective. If the trouble stays in the same channel, the trouble source is elsewhere in the system.

22. (a) right channel amplifier.

23. No output from either channel, or possible hum from both channels if the trouble is in the filter circuit.

24. The FM tuner and the switching section of the preamplifier/control unit.

25. The first check would be to switch to a different input unit. If operation is restored, the other input is at fault. However, if proper operation is not restored, the trouble is something that affects both channels. If a common power supply is used for both channels, this should be checked next. It may also be necessary to disconnect the amplifiers from the power supply, as a fault in one amplifier could affect the operation of the supply.

26. An oscilloscope.

27. (c) 180° phase shift.

28. True

29. Dolby type B

QUESTIONS

IMPORTANT—These instructions **MUST** be accurately followed to avoid loss, or errors in grading.

Indicate your answer on this sheet by filling in the box for the most correct answer to each question, as illustrated in the example below.

When all questions have been answered, place the answer card in the proper position to line up the boxes on the card with the boxes on the sheet.

Next, copy the complete lesson code into the space provided on the card, and fill in the answer boxes to correspond with those previously filled in on this sheet.

Before mailing, be certain your correct student number, name and address appear on the card.

LESSON CODE
7530A

Example: Honolulu is located on the island of
A ■ B ☐ C ☐ D ☐
(A) Oahu. (B) Newfoundland. (C) Guam. (D) Hawaii.

1. A ☐ B ☐ C ☐ D ☒
A music system having two or more separate channels is a
(A) monaural system. (B) integrated system. (C) component system. (D) stereophonic system.

2. A ☐ B ☐ C ☒ D ☐
A music system employing a separate tuner, turntable, amplifier and speaker system is called
(A) a monaural system. (B) a stereo system. (C) a component system. (D) an integrated system.

3. A ☐ B ☐ C ☐ D ☒
The IHF power output specification is given at a test frequency of
(A) 100 Hz. (B) 10 kHz. (C) 1.5 kHz. (D) 1 kHz.

4. A ☐ B ☒ C ☐ D ☐
With respect to amplifier power ratings,
(A) music power and sinewave power ratings are always the same. (B) music power ratings are always lower than sinewave ratings. (C) music power is never used. (D) music power ratings are often higher than sinewave power ratings.

5. A ☐ B ☒ C ☐ D ☐
The ability of a tuner to reject an undesired signal on the same channel is called
(A) S/N ratio. (B) capture ratio. (C) drift. (D) selectivity.

6. A ☐ B ☐ C ☐ D ☒
In four channel recordings, the ambiance signal represents
(A) the sum of the left and right channel signals. (B) the difference between the left and right channel signals. (C) the left channel signal. (D) information pertaining to sound reflection in the recording studio.

7. A ☐ B ☐ C ☐ D ☒
The quickest way to check speaker systems in a stereo system is to
(A) measure their resistance. (B) check the signal voltage at each speaker. (C) use an oscilloscope. (D) interchange the speakers between channels.

8. A ☐ B ☐ C ☒ D ☐
If one channel of a stereo system is incorrectly phased,
(A) there will be too much bass. (B) that channel will be lower in output than the other channel. (C) the stereo image will be indistinct, and bass will sound weak. (D) the overall sound level will increase.

9. A ☒ B ☐ C ☐ D ☐
A loud hum heard from one channel when listening to records indicates that
(A) the ground lead for that channel's signal cable is open. (B) the input to that channel is shorted. (C) there is no ground connection between the record player and the amplifier. (D) the pickup cartridge is completely inoperative.

10. A ☐ B ☒ C ☐ D ☐
A modern solid-state stereo amplifier will deliver the most output power to
(A) an 8-ohm load. (B) a 4-ohm load. (C) two speakers connected in series. (D) a 16-ohm load.

TROUBLESHOOTING HIGH-FIDELITY AMPLIFIERS

7535

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PRINTED IN USA

The stereo receiver is a common unit found in component hi-fi/stereo systems. The receiver shown includes an AM-FM/FM stereo tuner, stereo preamplifier control unit and a stereo power amplifier.

Courtesy Electrovoice

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> *There is no man living who can afford to kick from under him the ladder on which he climbed to success. What I have accomplished would soon be dissipated if I became self-satisfied and relaxed my effort.*
>
> *—William Wrigley Jr.*

TROUBLESHOOTING HIGH-FIDELITY AMPLIFIERS

Some of the highest quality electronic equipment available falls into the category of high-fidelity amplifiers. Almost unmeasurable distortion, signal-to-noise ratios of 120 dB (one million to one), highest reliability, and virtually complete protection against electronic destruction are obtainable. However, even the finest equipment may malfunction, and it is therefore important to know how to repair such equipment. The term high fidelity is also applied to almost every type of home music system, from simple portable phonographs to expensive console systems. Some of these systems are capable of high-fidelity performance and most of them are designed for stereo operation. However, some of the small portable phonographs are referred to as "stereo compatible." These units have stereo phono pickup cartridges but only single channel amplifiers. The two outputs from the phono pickup are connected together and applied to the input of the single channel amplifier. This arrangement allows stereo records to be played without damage. If a stereo recording is played with a monaural pickup, the recording may be damaged.

The amplifier of a portable phonograph is quite simple compared to that found in an expensive component system. Both types will be covered in this lesson. Almost without exception, modern music systems employ transistorized amplifiers. Integrated circuits are also being used more and more in home music systems.

The fact that most music systems are designed for stereo operation provides the service technician with a built-in servicing feature. Unless a problem is common to both channels (power supply troubles, etc.), the operation of one channel can be compared to that of the other channel to find the cause of the trouble. The defective circuit can be found by signal injection or signal tracing techniques. Comparisons of voltage and resistance readings between the two channels will normally point out the defective components.

SERVICING PRECAUTIONS

There are several precautions that must be followed when servicing hi-fi and stereo amplifiers. The most important precaution is to never operate an amplifier without a load. The load can be the speaker or speaker system associated with the amplifier, or a resistance equal to the speaker impedance and wattage. A load resistor is often more suitable for testing, especially at high levels. Some transistorized amplifiers can be operated without a load with no danger of damage. Unless you are absolutely sure of this, never operate an amplifier without a load.

Another precaution is not to solder in a circuit that is connected to the ac line. Soldering irons often have leakage between the heating element and tip. This could damage a unit connected to the line. Always unplug the unit when soldering, if it is line operated.

Care should also be exercised when removing or replacing components on a printed circuit board. Use only as much heat as necessary. A low-wattage iron is preferred to a soldering gun. To prevent damage, support the board while working on it. Also, be sure that you do not break any of the connecting wires attached to the board.

PORTABLE PHONOGRAPH AMPLIFIER

Figure 1 shows the schematic diagram of an amplifier found in a typical portable phonograph. This unit employs a ceramic stereo phono pickup with the left channel (L) and right channel (R) outputs tied together and applied to a single amplifier. Thus, stereo recordings can be played without damage. Most monophonic cartridges do not have sufficient vertical compliance of the stylus assembly to prevent damage to the grooves of a stereo record.

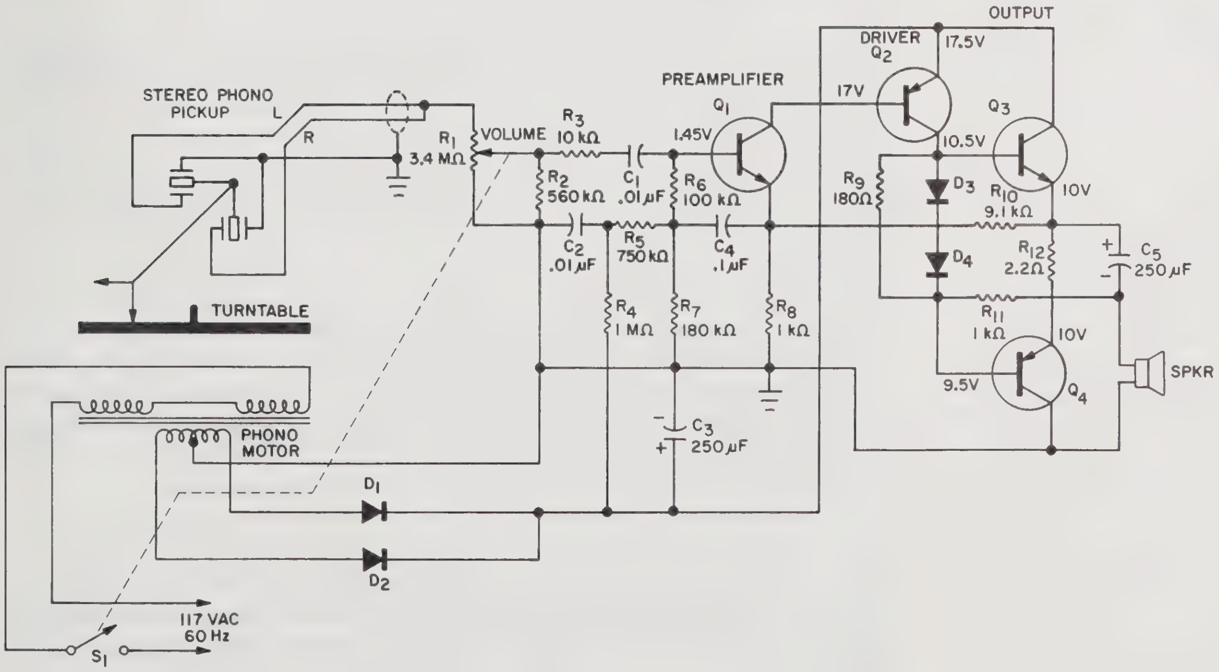


Figure 1

The power supply of the circuit of Figure 1 is a conventional full-wave rectifier formed by D_1 and D_2, with C_3 filtering the dc output. In place of a step-down power transformer, a winding placed on the phono motor provides the low ac voltage for the rectifier circuit.

The combined signal from the L and R outputs of the stereo pickup appears across R_1, the volume control. This signal is coupled through R_3 and C_1 to the base of Q_1. Bias for the Q_1 stage is supplied by R_4, R_5 and R_7, which are connected to the collector supply.

In the circuit of Figure 1, C_4 provides feedback from the emitter of Q_1 back to the base of Q_1. This arrangement provides negative feedback which increases the input impedance of the Q_1 stage. A high input impedance is necessary to prevent loading of the ceramic pickup, which would adversely affect frequency response.

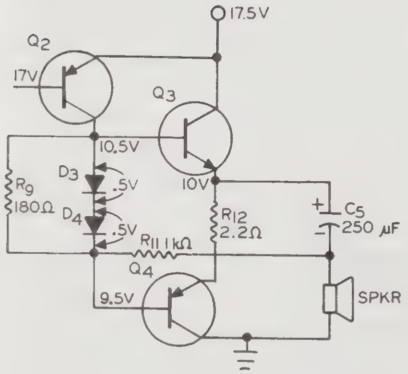


Figure 2

The output from preamplifier stage Q_1 is direct coupled to the Q_2 driver stage. In turn, the Q_2 output signal is direct coupled to the bases of the Q_3Q_4 complementary-symmetry power output stage. The use of a complementary-symmetry output stage removes the need for a phase inverter. R_{10} provides negative dc feedback to stabilize the amplifier. Care must be exercised when servicing a direct-coupled amplifier such as this, as a fault in one stage can affect the voltages in the other stages.

The complementary-symmetry form of output stage is very popular in modern hi-fi circuits. The driver and output stage of Figure 1 have been redrawn in Figure 2, with the operating voltages shown. The emitter of Q_2 is connected to the +17.5-volt supply and its base is connected to the collector of Q_1 which is at +17 volts with no signal present. As a result, the base of PNP transistor Q_2 is .5 volt negative with respect to its emitter, providing the proper forward bias.

The +10.5 volts at the collector of Q_2 is applied to the base of Q_3. This forward biases Q_3 because its emitter is at +10 volts. Bias diodes D_3 and D_4 each have a constant .5 volt drop. This places the base of Q_4 at +9.5 volts. Since emitter resistor R_{12} has a very small resistance, the emitters of Q_3 and Q_4 have the same potential, +10 volts. With +10 volts on its emitter and +9.5 volts on its base, PNP transistor Q_4 is also forward biased.

Proper operation of this circuit depends upon maintaining the correct dc voltages. The feedback established by R_{10} in Figure 1 keeps the dc voltages constant. For example, suppose that the voltage at the emitter of Q_3 becomes more positive than +10 volts. Since the emitter of Q_1 is coupled to this point through R_{10}, the emitter of Q_1 becomes more positive. This decreases Q_1 collector current and increases Q_1 collector voltage. The increased Q_1 collector voltage applied to the base of Q_2 reduces the forward bias on Q_2. In turn, the voltage drop from collector to emitter of Q_2 increases, thus decreasing the voltage at the collector of Q_2. Since the base of Q_3 is connected to the collector of Q_2, the decreased base voltage reduces the forward bias on Q_3. In turn, the voltage drop across Q_3 increases, bringing its emitter voltage back to normal. At the same time, the reduced voltage at the collector of Q_2, coupled to the base of Q_4 through D_3, D_4 and R_9, increases the forward bias on Q_4. This also tends to reduce the voltage at the emitters of Q_3 and Q_4. The opposite conditions occur when the voltage at the emitters of Q_3 and Q_4 starts to decrease.

The complementary-symmetry output stage operates Class AB, although this type of stage is often referred to as a Class B stage. Both transistors are forward biased slightly during no-signal conditions to reduce crossover distortion. Under signal conditions, one transistor is reverse biased while the other conducts, during positive alternations of a signal waveform. During the negative alternations, opposite conditions occur. For example, when the signal at the collector of Q_2 goes more positive, Q_3 is driven into conduction while Q_4 is cut off. On the opposite alternation, when the signal at the collector of Q_2 goes less positive (negative direction), Q_3 is cut off while Q_4 conducts.

In addition to developing the proper forward bias voltages for Q_3 and Q_4, diodes D_3 and D_4 provide temperature compensation. As temperature increases, the voltage drops across the diodes decrease slightly. This, in turn, reduces the forward bias on Q_3 and Q_4, counteracting any increase in collector current caused by a temperature increase.

The speaker is capacitively coupled to the junction of the emitters of Q_3 and Q_4. The charge and discharge of C_5 through the speaker produces the audio output signal. When Q_3 is conducting and Q_4 is cut off, C_5 charges through Q_3. On the other alternation, when Q_3 is cut off and Q_4 is conducting, C_5 discharges through Q_4. R_{11}, connected from the speaker back to the base of Q_4, provides additional negative feedback to stabilize the circuit.

Servicing Procedures

Servicing the phono amplifier of Figure 1 is not much different than servicing the audio section of a radio receiver. There are, however, mechanical problems that can occur with the turntable and pickup assembly. A common complaint is distorted sound. This is often caused by a worn pickup stylus. A small stylus inspection microscope can be used to check the pickup. Another mechanical problem is speed variations caused by slippage in the turntable assembly. This can often be cured by careful cleaning and lubrication. In

This photo shows a typical combination radio phonograph designed for home entertainment music systems.
Courtesy General Electric, Audio Products Dept.

some cases, drive system components such as belts, pulleys, etc., may have to be replaced.

The amplifier of Figure 1 uses a line-operated power supply and there are no batteries to cause trouble. However, there are a large number of portable phonographs in use that employ battery power. Always check the batteries first in such units. Since many of these portable units are used at beaches, etc., they receive rather rough treatment. Check for accumulations of sand, dirt, etc., if mechanical problems are encountered.

The first troubleshooting step is to observe the operation of the equipment and determine what symptoms are caused by the trouble. Unless the customer has indicated that the unit blows fuses, smokes, etc., plug the unit in and check the operation. The phonograph of Figure 1 is quite simple, and only a short circuit in the motor, line cord or switch would draw enough current to blow a fuse, cause burning or cause smoke to appear.

With the unit operating, place a record on the turntable and determine if any sound can be produced. Let's assume that no output occurs. The volume control provides a convenient signal injection point. In this case, it divides the unit into two sections, pickup and amplifier. Touch the ungrounded end of the volume control with a screwdriver. If a hum or a click is produced in the speaker, you can be reasonably sure the trouble is ahead of the amplifier. The problem could be a defective pickup, broken wires in the pickup arm, etc. The wires can be checked with an ohmmeter. If no problem exists here, the trouble is probably in the pickup unit itself. DO NOT check the leads of a magnetic cartridge with an ohmmeter, as this may burn open the fine wire coils of the cartridge. An oscilloscope or signal tracer can be used to check the pickup output. Most of the ceramic and crystal pickup units employed in this type of phonograph produce outputs ranging from several tenths of a volt up to a volt. The crystal type pickup units produce the higher outputs. In some units, enough signal cannot be injected at the volume control with a screwdriver, and an audio oscillator or signal injector must be used. Experience will dictate the type of signal injection to use.

If no output is produced when a signal is injected at the volume control, the trouble is in the amplifier or power supply. The power supply can be checked quickly by measuring its output voltage. A condition of no output voltage could be caused by defective diodes, an open motor winding or a shorted filter capacitor. You can use your ohmmeter to check these components. It may be necessary to disconnect one end of the component being checked to eliminate circuit loading effects when making resistance measurements.

Assuming that the power supply is operating properly, the trouble is in the amplifier if no output is obtained when a signal is injected at the volume control. The direct-coupled nature of the amplifier can present some service problems. A trouble in one stage is likely to affect the other stages. Since bias voltages are especially critical in a direct-coupled amplifier, it is important that your meter have an accurately calibrated low-voltage scale.

It is often difficult to employ conventional signal tracing ~~or substitution methods in direct-coupled amplifiers.~~ Because the bias for any stage of a direct-coupled amplifier is controlled by the preceding stage, it is sometimes difficult to locate the defective stage. It is a good idea, however, to signal trace or signal inject as far as you can to eliminate as many stages as possible from consideration as the trouble source. When a suspect stage is located, the transistor element voltages are then CAREFULLY measured and compared to those specified by the manufacturer. This will usually point out the source of trouble. In some circuits operating failure of one transistor may upset the bias in the other stages to the point where excess currents are drawn and other transistors are destroyed.

The transistors most subject to failure in a circuit of this type are the output transistors. As an example, let's assume that Q_4 develops a collector-to-base short, as shown in Figure 3. The voltages circled are the normal operating voltages. The uncircled voltages are those present with Q_4 shorted. Under these conditions there is no output, and signal tracing or signal injection shows that the output and driver stages are defective. A signal would probably pass through a preceding stage, but no further. As shown in Figure 3, the base voltage of Q_4 is zero. The base-emitter junction voltage drop places the Q_4 emitter at about .5 volt. The voltage drop across R_{12} places the Q_3 emitter at approximately .6 volts. Since the base-collector circuit of Q_4 is the collector load of Q_2, the voltage at the collector of Q_2 is equal to the drop across the bias diodes, or about 1 volt. The voltage drops across the diodes are relatively constant. With the collector of Q_2 at 1 volt, Q_3 is still forward biased. However, Q_2 may draw excessive current and might be damaged. If this occurs, Q_3 may also be damaged.

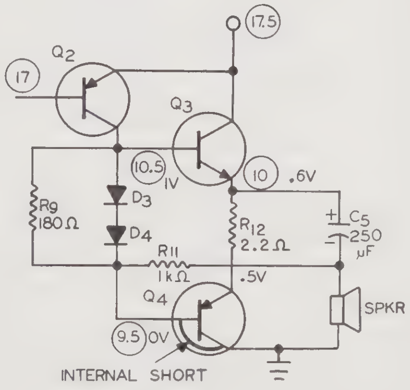


Figure 3

Voltage measurements taken in the Q_4 stage would quickly show that Q_4 has a collector-base short, as the base and collector voltages would be the same. For many amplifiers, if one transistor in the output circuit becomes defective, it is best to replace both. The output transistors are generally supplied as a matched pair when almost identical characteristics are needed for proper circuit operation. In a circuit of this type, it is best to begin with voltage measurements in the output stage and work backward to the last stage that passes a signal.

To illustrate how a defect in an early stage of an amplifier upsets all the following stages, assume that the pc board connection to the base of Q_1 is open. Figure 4 shows the basic circuit of Figure 1 under these conditions. All circuits preceding the Q_1 base have been left out of the figure for clarity. Under these conditions, the amplifier is inoperative. The uncircled voltages are those obtained with the base connection to Q_1 open.

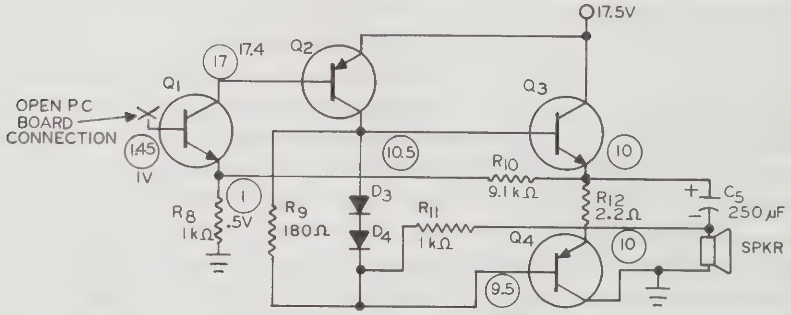


Figure 4

With the base circuit of Q_1 open, there is no forward bias on Q_1 and it only conducts a small leakage current. Since Q_1 collector current forms the Q_2 base current, the forward bias on Q_2 is also decreased. This, in turn, upsets the bias on Q_3 and Q_4. Measurement of the transistor terminals, from the output stage back to the preamplifier, would show a shift from the normal values. Since the bias on Q_1 controls all of the following stages, the defect must lie in the Q_1 stage. The low base and emitter voltages on Q_1 indicate a fault in the Q_1 bias circuit. Measuring the voltage on the other side of the break in the pc board will indicate a higher than normal voltage.

Depending upon the circuit design, signal injection in the driver and output stages may still produce an output. It is difficult to set down any hard and fast method of procedure for pinpointing the problem source. The most useful procedure is careful measurement of the transistor terminal voltages. If the unit is a stereo type with two amplifier channels, the readings in one channel can be used to find the defect in the other channel.

INTEGRATED STEREO AMPLIFIER

Figure 5 shows the schematic diagram of one channel of an integrated stereo amplifier. This circuit is representative of the types found in console home entertainment music systems. The amplifier for the other channel would be identical to the one shown in Figure 5.

The input source is selected by switch S_1, which applies the input signal to the base of Q_1, the preamplifier stage. S_2 is used to short the inputs to the two channels together when a monaural signal is applied to the amplifier. Q_1 operates as an emitter follower and the negative feedback provided by C_2 increases the input impedance of the stage. Since a ceramic pickup is used, no equalization circuitry is necessary to obtain the proper cartridge output, other than the high input impedance of the circuit.

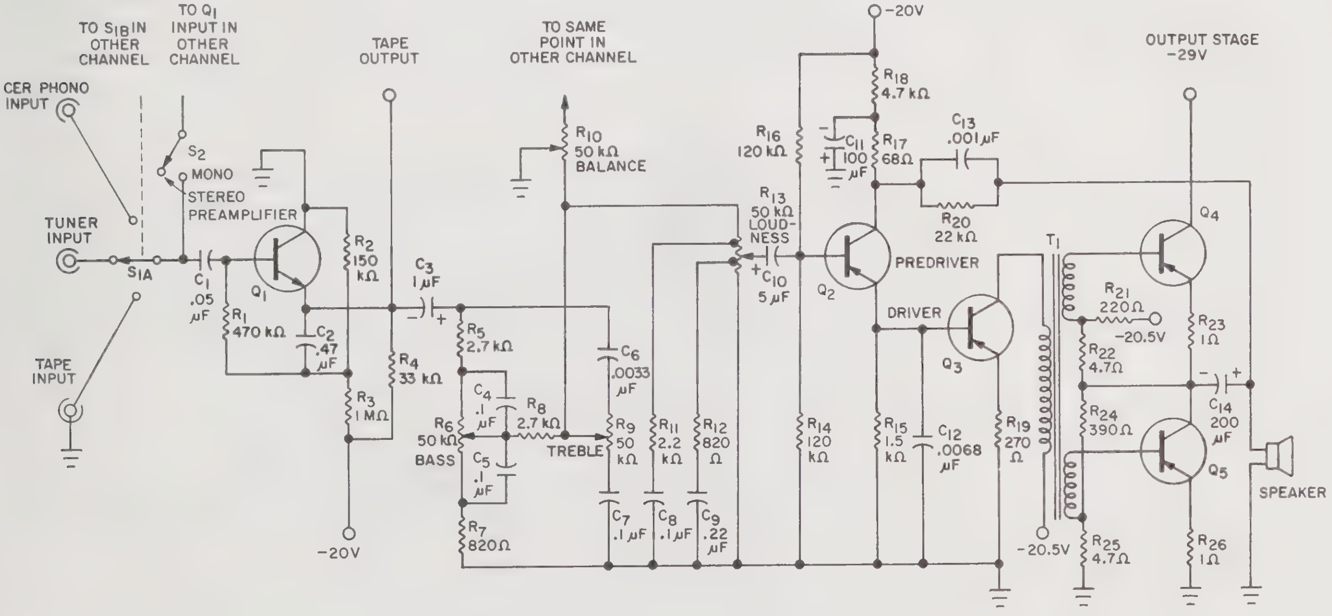


Figure 5

The output signal from the Q_1 stage is coupled to the tone and loudness control circuit through C_3. R_5, R_6, R_7, C_4 and C_5 form the bass control circuit. The bass control circuit has been redrawn in Figure 6. With the movable contact at the center of its rotation, as in Figure 6A, there is no boost or attenuation of the low frequencies and the control is at its "flat" position. Figure 6B shows the circuit when the movable contact of the bass control is at the top of the potentiometer. Under these conditions, C_4 is out of the circuit and the output increases as frequency decreases. This results from an increase in the reactance of C_5 as frequency decreases. The circuit now provides maximum "bass boost."

Figure 6C shows the bass control R_6 with the movable contact at the bottom of the potentiometer. Under these conditions, C_5 is shorted out, and the reactance of C_4 increases with a decrease in frequency, causing a reduction in output as frequency decreases. The bottom position of the R_6 movable contact thus provides maximum "bass attenuation."

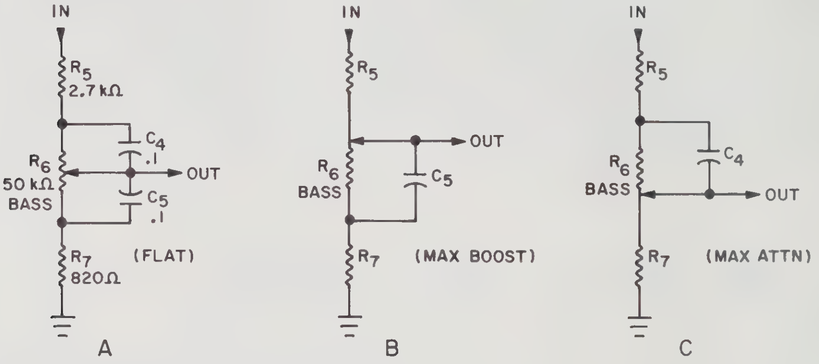


Figure 6

The output signal from the Q_1 stage is also applied to the treble control circuit consisting of C_6, R_9 and C_7. The treble control circuit has been redrawn in Figure 7. With the movable contact of R_9 in the center position, as shown in Figure 7A, no boost or attenuation occurs with an increase in frequency and thus the control is at its "flat" position.

Figure 7B shows treble control R_9 with its movable contact at the top of the potentiometers. Under these conditions, the decrease in reactance of C_6 as

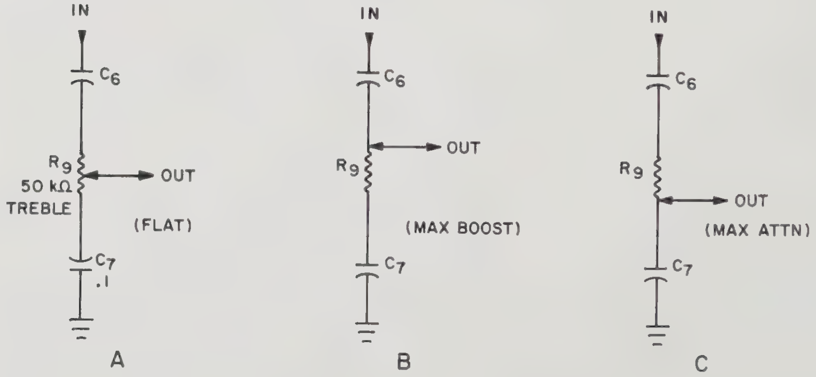


Figure 7

frequency increases causes an increase in output as frequency increases. Thus, R_9 now provides maximum "treble boost." Figure 7C shows the circuit with the movable contact of treble control R_9 at the bottom of the potentiometer. Under these conditions, the decrease in the reactance of C_7 as frequency increases causes the output to decrease as frequency increases. Thus, the circuit now produces maximum "treble attenuation."

The combined output from the bass and treble controls is applied to the balance and loudness controls. The balance control is arranged to shunt the output of either channel. By varying the balance control, the output of either channel can be increased above the level of the other to compensate for different input signal levels to the two channels.

The sensitivity of the human ear is not the same to all frequencies. As the sound level is decreased, the ear's response drops off at both low and high frequencies. Figure 8 shows a graph of the sensitivity of the human ear to different frequencies at various sound levels. The curves of Figure 8 are referred to as the Fletcher-Munson curves, after the engineers that performed the experimental work to develop them.

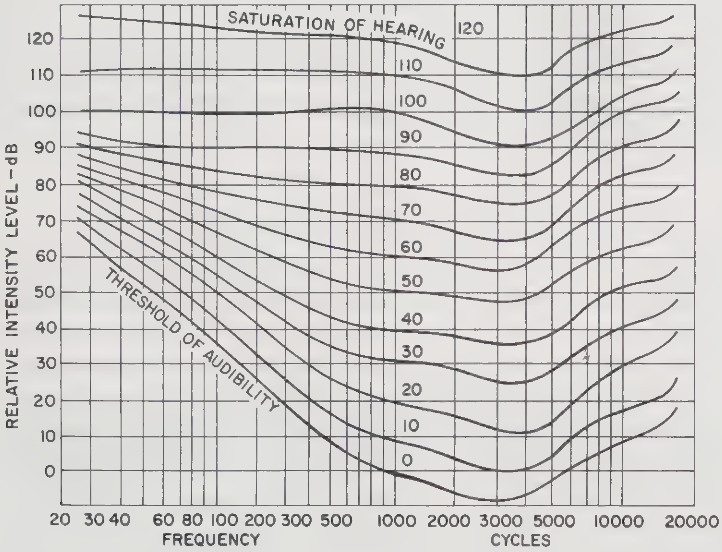


Figure 8

To compensate for the response of the human ear, both the high- and low-frequency signal levels should be boosted as the volume level is decreased to provide a flat response. Since the high-frequency drop-off is not as great as the low-frequency drop-off, good results can be obtained by just boosting the low frequencies at low volume levels. This arrangement is provided by the **LOUDNESS CONTROL**, R_{13}, and its associated components in Figure 5. A level or volume control is referred to as a loudness control when it compensates for the ear's frequency response. The increase in the reactance of C_8 and C_9 as frequency decreases causes an increase in the voltage from the taps on R_{13} to ground. Thus, as the movable contact on R_{13} is rotated to lower the volume level, the low frequencies are boosted.

The output signal from the loudness control is fed to Q_2 for further amplification. Q_2 is direct coupled to the Q_3 driver stage. The output signal from the driver stage is transformer-coupled to the Q_4Q_5 power amplifier. The driver transformer provides the necessary phase inversion for the output stage. Bias provided by R_{21}, R_{22}, R_{24} and R_{25} sets the operating point of Q_4 and Q_5 just above the Class B point to eliminate crossover distortion. Although Q_4 and Q_5 are actually operating Class AB, the output stage is usually referred to as a Class B output stage. Negative feedback provided by C_{13} and R_{20} stabilizes the amplifier operation and reduces distortion.

Servicing Procedures

Although the amplifier of Figure 5 is more complex than the circuit of Figure 1, it is no more difficult to service. In fact, it may be much simpler to service because the entire circuit is not direct coupled. Assuming that a trouble has been traced to one of the amplifier channels, either signal tracing or signal injection can be employed to locate the defective stage. Once the defective stage is found, voltage and resistance measurements can be used to locate the defective component or components.

To illustrate the troubleshooting of an amplifier like that of Figure 5, assume that coupling capacitor C_{10} is open. The symptom would be no output from the amplifier. Using an audio generator, a signal to the push-pull output stage could be injected at the base of either Q_4 or Q_5. A low output with some possible distortion would be obtained, since both transistors are not being driven at the same time. However, the test would prove that the output stage is operating. The output from the audio generator can now be applied to the base of the driver transistor, Q_3. With the indicated trouble, an output would still be obtained. When injecting signals, always start with the output level as low as possible and then advance it to obtain a usable output. This will prevent overdriving the stage and possibly damaging some of the components.

The output from the audio generator is now applied to the base of Q_2, and again an output is obtained. However, when the generator output signal is moved to the movable contact or top contact of loudness control R_{13}, no output is obtained. This indicates that the defective component is coupling capacitor C_{10}. With C_{10} open, it can be paralleled with another capacitor and normal operation would return. Testing C_{10} on a capacitor tester would show that it is open.

An ohmmeter can often be used to check an electrolytic capacitor such as C_{10}. When the meter is first connected, the meter pointer will deflect to near zero ohms and then as the capacitor charges, the resistance will increase to beyond about 50K ohms. With an open capacitor, no meter pointer deflection would be obtained.

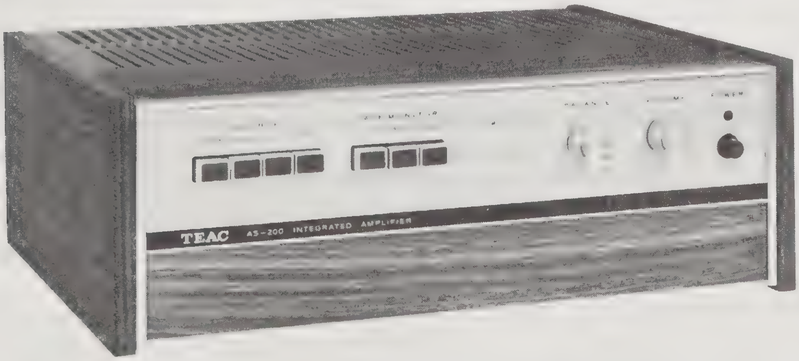
Rather than start the signal injection tests at the output stage, the test signal can be injected at the loudness control. This divides the amplifier into two sections. If an output is produced when the signal is injected at the loudness control, then all the stages following the control are operating and the trouble lies ahead of the loudness control. If no output is produced when the signal is injected at the loudness control, the trouble follows the loudness control.

Signal tracing may also be used to troubleshoot the amplifier. With this method, the signal can be traced from the input to the amplifier output to locate the defective stage. Of course, this method requires an input from a signal generator or one of the inputs such as the tuner or phonograph. The signal tracer output can also be placed at the loudness control to divide the amplifier into two sections if desired.

Some of the input signals to a high-fidelity amplifier are very low in amplitude. The outputs obtained from magnetic phono cartridges and tape playback heads are often in the 1 to 10 mV range. These signals must also be equalized, or frequency corrected, to compensate for the equalization that is used when recording.

LOW-LEVEL INPUT STAGES

To prevent excessive groove width at low frequencies and reduce noise at high frequencies, the amplifiers that drive the cutting heads for disc



An integrated stereo amplifier is shown that contains both a preamplifier control unit and a 50-watt-per-channel power amplifier.

Courtesy TEAC Corporation of America

recordings use the RIAA (Record Industry Association of America) frequency equalization recording curve shown in Figure 9. Note that the recording curve shows the low frequencies attenuated and the high frequencies boosted. To provide a flat frequency response on playback, the output of the pickup must be applied to a network that has a response opposite to the recording curve, as shown in Figure 9. When a ceramic pickup is used, equalization is not necessary. The electrical characteristics of the pickup provide the necessary equalization to produce a near-flat frequency response. Some expensive amplifiers include additional frequency compensation networks to make the playback response follow the RIAA curve more closely. However, when a magnetic pickup is employed, an RIAA equalization network must be included in the preamplifier stage, since the magnetic pickup does not provide any equalization. In addition, because the output level of a magnetic pickup is very low, additional stages of amplification are required.

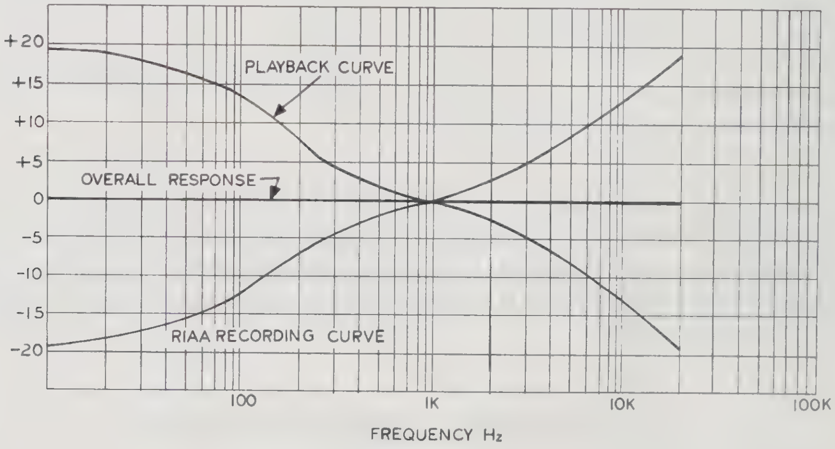


Figure 9

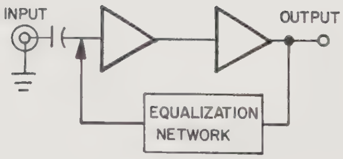


Figure 10

A typical magnetic phono preamplifier is shown in block diagram form in Figure 10. These are high-gain circuits in which the signal strength is increased 60 dB or more. Therefore, extensive precautions must be taken in designing these circuits to ensure that hum and noise are not amplified along with the desired signals. All signal and ground paths must be kept short. Low noise resistors are usually employed, the first stage transistors are often individually selected for low noise outputs, and shielding is often provided for the circuits. To retain the quality of a circuit of this nature, any replacement part must be the equivalent or a duplicate of the original component.

In those amplifiers that have tape head inputs, the phono preamplifier is also used as the tape head preamp. The selector switch is used to change the input to the preamp and to change the equalization network being used. The tape playback equalization is somewhat similar to the phono equalization. Obtaining accurate tape playback equalization usually requires a circuit that

The following Practice Exercise questions cover the subjects which you have just studied. They are:

SERVICING PRECAUTIONS

PORTABLE PHONOGRAPH AMPLIFIER

SERVICING PROCEDURES

INTEGRATED STEREO AMPLIFIER

SERVICING PROCEDURES

1. What built-in servicing feature is found in a stereo amplifier?
2. In general, an amplifier can be operated without a speaker or suitable load when it is being serviced. True or False?
3. What type of soldering iron is the most suitable for printed service work?
4. What is the purpose of R_{10} in Figure 1?
5. Explain the circuit action if the voltage at the emitters of Q_3 and Q_4 in Figure 1 tries to decrease.
6. An increase in temperature increases the voltage drop across D_3 and D_4 in Figure 1. True or False?
7. Distortion in a phonograph system can often be a result of a worn pickup stylus. True or False?
8. What is the most convenient point in the circuit of Figure 1 to inject a test signal?
9. How can you check rectifier diodes with an ohmmeter?
10. Signal injection and tracing are the best means of tracing troubles in a direct-coupled audio amplifier. True or False?
11. When a transistor is shorted the voltages at the two shorted terminals will be the same. True or False?
12. A change in the collector voltage of Q_1 in Figure 1 will cause a change in the bias on Q_3 and Q_4. True or False?
13. What is the purpose of C_2 in the Q_1 stage of Figure 5?

14. In Figure 6, maximum bass boost is obtained with the slider of R_6 at the (a) center, (b) bottom, (c) top.

15. In Figure 7, what effect does the treble control have on the high-frequency response when the slider is at the center position?

16. In Figure 7, maximum treble attenuation is obtained when the slider of R_9 is at the (a) center, (b) top, (c) bottom.

17. To compensate for the response of the human ear, the high and low frequencies must be attenuated. True or False?

18. How does R_{13} in Figure 5 serve as a loudness control?

19. The Q_4 and Q_5 stage in Figure 5 actually operates Class (a) A, (b) B, (c) AB.

20. Suppose C_3 is open in the circuit of Figure 5. Describe the symptoms and the tests you would make to find the fault.

21. Electrolytic capacitors can be checked with an ohmmeter. True or False?

is matched to the characteristics of the particular type of tape playback head being used. For this reason, most high-quality tape machines usually are equipped with their own playback preamplifiers.

QUASI-COMPLEMENTARY-SYMMETRY OUTPUT STAGE

The amplifier circuits shown previously employed a direct-coupled complementary output stage and a transformer-coupled Class B output stage. As solid-state high-fidelity amplifiers increased in popularity, more types of high-quality transistors became available for high-power applications.

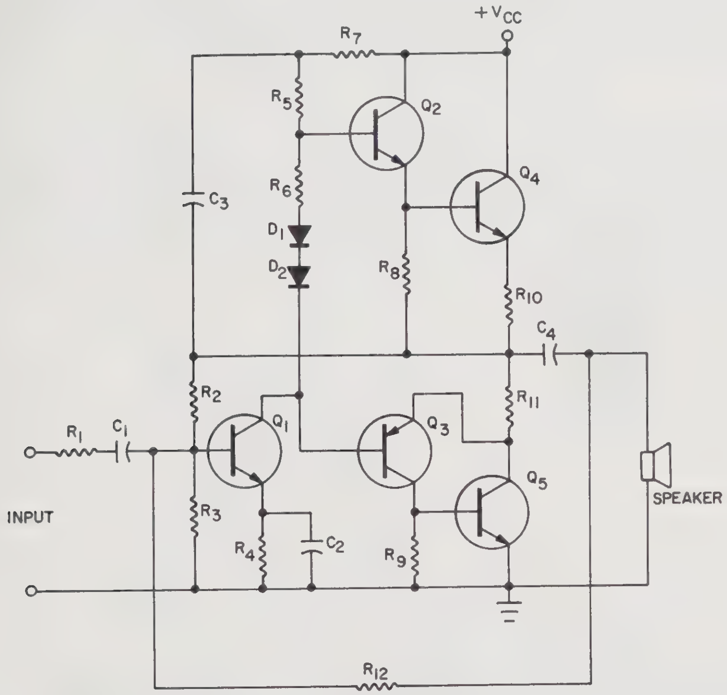


Figure 11

Transistorized amplifiers are presently available with output ratings of more than 1000 watts per channel, and outputs of 60 to 100 watts are now as common as 40- to 60-watt outputs were with tube amplifiers. The amplifiers with extremely high outputs are also very expensive. Until recently, a PNP silicon output transistor was very expensive. Most of the commonly available 60 to 100-watts-per-channel amplifiers were designed to not require the expensive PNP output transistors. This is accomplished by use of the quasi-complementary-symmetry output stage shown in Figure 11. This circuit employs a PNP-NPN complementary-symmetry driver stage and an NPN output stage. The complementary-symmetry driver stage eliminates the need for a driver transformer. Elimination of the driver transformer eliminates the phase distortion introduced by a driver transformer. The result is an amplifier with greater stability. Q_3 is both a phase inverter and driver for Q_5.

Servicing procedures for the circuit of Figure 11 are similar to those for the output stages in Figures 1 and 5. Since the circuit is direct coupled, care must be taken when making voltage measurements. Remember, a shift of one-tenth of a volt can upset the entire circuit. If one of the drivers or output transistors should become defective you should replace the pair. Matched pairs of driver and output transistors are necessary for proper circuit operation.

FULL COMPLEMENTARY-SYMMETRY OUTPUT STAGE

Some expensive high-power amplifiers use full complementary-symmetry output stages. No phase inverter is required, and the opposite temperature characteristics of the NPN and PNP transistors tend to compensate each other. The use of completely complementary circuitry also affects a further reduction of distortion in the amplifier. A typical circuit is shown in Figure 12.

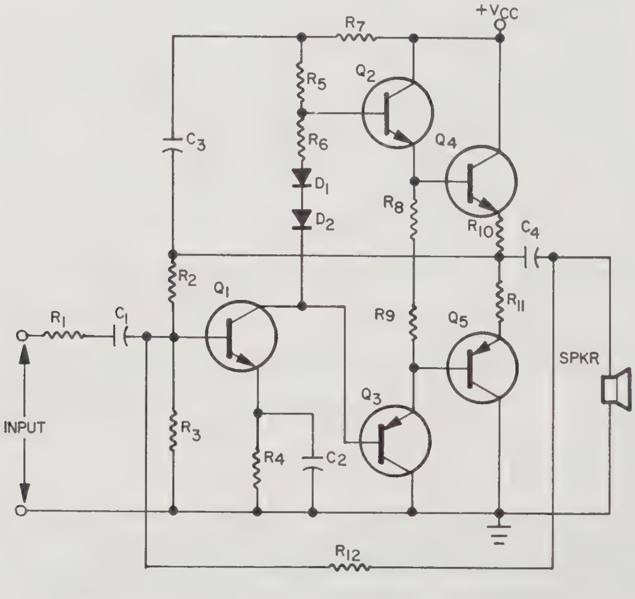


Figure 12

A further improvement in amplifier performance is obtained if separate positive and negative voltage supplies are used. This places the output of the amplifier at dc ground potential, which allows the speaker to be connected directly to the output of the amplifier, as shown in Figure 13. Note the addition of fuse F_1, which has been added to protect the speaker voice coil from any dc voltage which may be applied in the event of a malfunction of the amplifier. Any resistance or impedance placed in series with the speaker leads will cause some degradation of low-frequency performance.

Typical values for C_4 of Figure 12 are 2000 to 3000 μF. For a 20-Hz signal, this places about 2.7 to 4 ohms in series with the speaker. Eliminating the capacitor eliminates this series impedance.

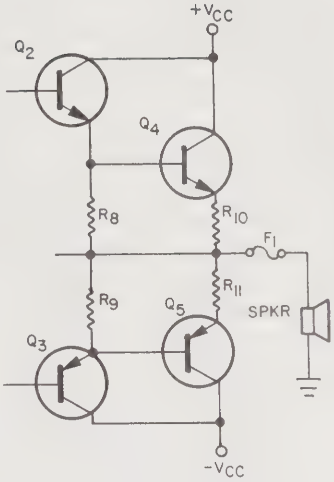
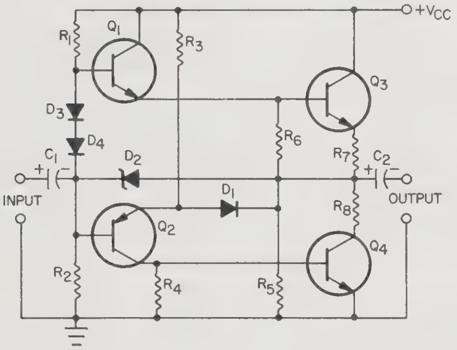


Figure 13

OVERLOAD PROTECTION

Most solid-state high-fidelity amplifiers employ some kind of output overload or short-circuit protection. The simplest protection is a fuse in series with the output load. Circuit breakers are sometimes used in place of fuses in amplifiers that can withstand a shorted output for a longer period of time than that needed to blow a fuse. A circuit in which the amplifier shuts itself off when the load is short-circuited is shown in Figure 14.



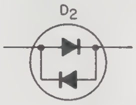


FIGURE 14A

Figure 14

Since Q_1 and Q_3 are emitter followers, they provide current gain but no voltage gain. The resistance values in the Q_2 and Q_4 circuitry are selected so they also provide current gain but no voltage gain. Thus, the input signal to Q_1 and Q_2 is power amplified in the normal fashion by the four transistors and is coupled through C_2 to the speaker.

Diode D_1 provides dc feedback from the Q_3 emitter—Q_4 collector junction to the Q_2 emitter to help maintain equal dc voltage drops across Q_3 and Q_4.

Diode D_2 is constructed so that it functions like the two diodes shown in Figure 14A. That is, D_2 conducts when the voltage across it exceeds a peak amplitude of .6 volts of either polarity. Normally, the amplitude of the signal voltages at the output and input are equal. Also, the dc voltages at each terminal of D_2 are equal. Thus, D_2 is normally non-conductive.

If the output terminals are short circuited, an input signal voltage whose peak amplitude is greater than .6 volt, causes D_2 to conduct, shorting the output terminals to the input terminal. Thus, the input (and output) signal voltage is limited to .6 volt peak amplitude which, in turn, limits the current through the output transistors to a safe value.

POWER SUPPLIES

The power supplies used in most hi-fi stereo amplifiers are conventional full-wave or bridge rectifiers. A step-down transformer is used to obtain the desired low ac voltage for the rectifier. With high-voltage transistors, some units are operated directly from the ac line with a simple half-wave rectifier. Some amplifiers use fully regulated power supplies to decrease distortion and increase low-frequency output at full power.

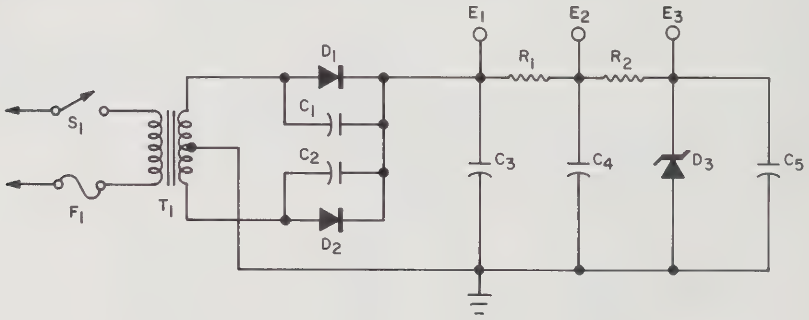


Figure 15

Figure 15 shows the schematic diagram of a typical low-voltage power supply. D_1 and D_2 form the full-wave rectifier. Capacitors C_1 and C_2, connected across the diodes, provide transient protection. C_3 and C_4, together with R_1 and R_2, form the filter and voltage divider. Zener diode D_3, together with C_5, provides a well-filtered regulated voltage for the critical low-level stages of the amplifier.

Power supply troubles generally affect both channels of a stereo amplifier unless there is a separate power supply for each channel. When there is complete failure of both channels, check the power supply first. Always check the fuse or circuit breaker before pulling the chassis.

With some fuses, a visual inspection is inconclusive. Use an ohmmeter to be certain of the fuse's condition. Also, connect the ohmmeter to the line cord plug, and check out the cord, switch and power transformer primary winding. If the unit has a turntable, etc., operating off the same line cord and switch circuit, and the turntable operates, you can rule out the line cord and switch circuit as problems. On some units, the amplifier power switch is mounted in the turntable or changer. You might have to remove the changer from its mounting to check the switch, if tests show this to be the problem.

In some cases, a problem in one channel can affect the power supply so that neither channel has any output. For example, a short in the power output stage of one channel could reduce the power supply output voltage. With a well designed circuit, however, the fuse or circuit breaker should open to prevent power supply damage. It may be necessary to disconnect both channels from the power supply and reconnect them one at a time to see if this is the cause of the trouble. Another method is to open the power lead to each channel and insert a current meter. Comparison of current readings will show if the problem is in one of the channels.

Since there are not many components in a power supply, it is quite easy to troubleshoot. An ac voltmeter can be used to check the transformer secondary. The diodes and dropping resistors can be checked with an ohmmeter. The filter capacitors can be checked with an ohmmeter or capacitor tester.

To illustrate the troubleshooting procedure for a power supply, let's assume that R_1 is open in the circuit of Figure 15. Both channels of the stereo amplifier would be inoperative during this condition. Checking the fuse and primary circuit with an ohmmeter would show no fault there. A dc voltage check at E_1 would show normal or slightly higher voltage. A dc voltage check at E_2 would show zero volts. A quick check of R_1 with an ohmmeter would show R_1 to be open. It is always best to start at the rectifier and work towards the lowest voltage point when measuring power supply voltage.

As another example, let's assume that D_1 is open. The symptom would probably not be total failure of both channels. The output on both channels would be lower than normal, with a higher than normal hum level. The symptoms would rule out primary circuit trouble. The low output and high hum level would tend to indicate a defective filter. However, careful observation of the hum frequency will show that it is 60 Hz, not 120 Hz. A bad filter in a full-wave supply will produce 120-Hz hum. Since this is 60-Hz hum and the supply is full wave, the trouble must be in the rectifier circuit. An ac voltage check of the transformer secondary would show it to be normal. An ohmmeter check of both diodes would show D_1 to be open.

Experience will show you how to recognize the difference between 60-Hz and 120-Hz hum. When 120-Hz hum occurs in a full-wave power supply, you can suspect the filter capacitors. An ohmmeter or capacitor tester will point out the bad unit. However, it is often quicker to disconnect one end of the suspected component and substitute a new one.

Semiconductor diodes can also become short circuited. This often occurs when a high-voltage transient on the line exceeds the diode's breakdown voltage. C_1 and C_2 help to prevent this from occurring. With one or both diodes in Figure 15 shorted, the fuse will open. An ohmmeter check will indicate the defective diode or diodes. If a diode has shorted, always check the transient suppression capacitors, C_1 and C_2.

Failure of zener diode D_3 will affect the voltage at E_3 and possibly at E_1 and E_2. If D_3 should open, the voltage at E_3 will probably increase. If D_3 should short, the voltage at E_3 drops to zero, and the increased current will probably cause fuse F_1 to open.

As mentioned earlier, an open filter capacitor causes a reduction in voltage and an increase of hum in the amplifier. A shorted capacitor will cause an increase in current and the voltage across the capacitor will drop to zero. The effects of C_5 shorting would be the same as when D_3 shorts. If C_4 should short, the voltage at E_2 and E_3 will be zero. The increased current through R_1 may damage it. If C_3 were to short, the fuse would open.

From the various examples given, you can see that several troubles can cause the same symptom. To isolate the trouble it may be necessary to disconnect one end of a suspected component when making measurements. For example, if D_3 is shorted, how would you determine if the short is in D_3 or C_5 without disconnecting one of them? Power supply problems can be deceptively simple, just as with a dc-coupled transistor amplifier.

Electronic Filters

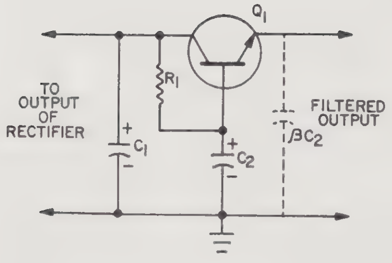


Figure 16

The low-voltage power supplies employed in transistor amplifiers require large values of filter capacitance to produce low values of ripple. Rather than use large bulky filter capacitors, an electronic filter can be used. Figure 16 shows the circuit of an electronic filter. Q_1 operates as an emitter follower between the output of the rectifier and the output of the power supply. With C_2 in the base circuit of Q_1, the apparent capacitance between emitter and ground is the value of C_2 multiplied by the current gain β, or h_{fe}, of the transistor. Thus, if C_2 has a value of 500 μF and Q_1 has a β of 50, the apparent output capacity is 500×50, or 25,000 μF. Since the effective capacitance is the product of β and C_2, the circuit is also referred to as a **CAPACITY MULTIPLIER.**

If excessive ripple is present in a circuit employing an electronic filter, you can suspect this circuit of having a defective component. A defect in either Q_1 or C_2 would cause a high ripple level. Q_1 can be checked with an ohmmeter or transistor tester. C_1 and C_2 can be checked with a capacitor tester or new units substituted for C_1 and C_2. When replacing Q_1 make sure that the current gain of the replacement transistor is at least the minimum value specified by the manufacturer. A lower value will reduce the effective output capacity.

Protective Circuitry

Some high-fidelity amplifier regulated circuits are designed to electronically shut off when their outputs are short-circuited. Figure 17 is a simplified schematic of a circuit of this type.

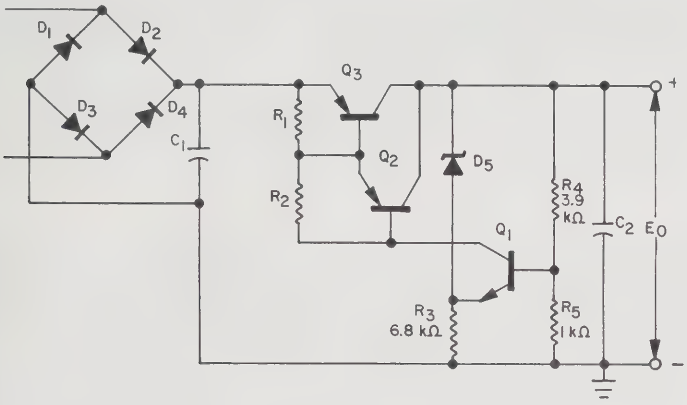


Figure 17

During normal operation, the regulator functions in the following manner. If output voltage E_O increases, the Q_1 base voltage increases. The Q_1 emitter voltage also increases because of the constant voltage drop across zener diode D_5. Because of the values selected for resistors R_3, R_4 and R_5, the Q_1 emitter voltage increase is greater than the increase of its base voltage. This condition decreases the forward bias of Q_1, causing its collector voltage to increase. The increased Q_1 collector voltage, tied to the Q_2 base, decreases the forward bias of the Q_2Q_3 Darlington circuit pass transistors. This results in a decrease of E_O at the output of the circuit, bringing it back to the original value.

If output voltage E_O decreases, the Q_1 base voltage decreases. Because of the constant voltage drop across D_5 and the resistor values in the circuit, the Q_1 emitter voltage decreases more than its base voltage does.

This condition increases the forward bias of Q_1, causing its collector voltage to decrease. The decreased Q_1 collector voltage increases the forward bias of Q_2 and Q_3. This results in an increase of E_O, bringing it back to its original value.

If the output voltage drops considerably because the circuit draws too much current or a short-circuit condition occurs, zener diode D_5 conduction stops, and the Q_1 emitter voltage increases enough to reverse bias Q_1. This increases the Q_1 collector voltage enough to reverse bias Q_2 and Q_3, opening the output voltage connection to the + terminal.

FREQUENCY RESPONSE AND DISTORTION PROBLEMS

Problem sources involving distortion, poor frequency response and the like are often more difficult to locate than the cause of a total failure. The oscilloscope is probably the most useful piece of test equipment to locate this type of trouble. Careful observation of input and output waveforms in each stage usually helps locate the defective stage. Voltage and resistance measurements can then be used to locate the defective component. When a stereo amplifier is being serviced, measurements in the defective channel can be compared to those in the good channel to help locate the trouble.

To illustrate how a change in gain can occur, consider the common-emitter amplifier stage shown in Figure 18. Suppose that emitter bypass capacitor C_1 opens. The effect would be a loss in gain due to the negative feedback provided by the unbypassed emitter resistor R_4. Voltage measurements would appear normal in the stage since the bias circuit has not been affected. Input and output measurements taken with an oscilloscope would show reduced gain when compared to the manufacturer's specifications or a similar stage in the other channel. Substituting a good capacitor for C_1 would restore normal gain.

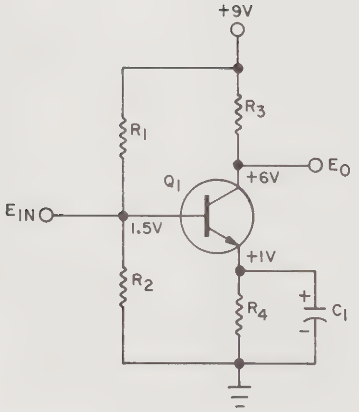


Figure 18

This example points out the need for a thorough understanding of circuit operation. This is actually one of your best "servicing tools." In the circuit of Figure 18 you would know that the only way the gain could be reduced, assuming Q_1 is biased properly, is if C_1 opens and negative feedback is introduced. If substitution of C_1 does not clear up the trouble, then Q_1 may be defective. Substitution or a check with a transistor tester would point out a defective transistor.

Distortion is usually caused by a bias shift in one or more amplifier stages. This is often a problem in direct-coupled amplifiers, as a defect in one stage can cause a shift in bias on the other stages.

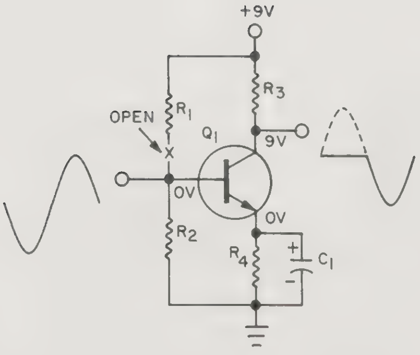


Figure 19

To illustrate the effect of a bias shift, suppose that the connection between the lower end of R_1 and the base of Q_1 opens in the circuit of Figure 18. This defect is shown in Figure 19. Note that the dc voltages on all elements of the transistor are affected. With the lead from R_1 open, there is no forward bias on Q_1 and it is operating Class B. Since Q_1 is an NPN transistor, it will conduct on the positive alternation of the input signal only and produce the output waveshape shown.

When testing audio circuits for distortion with an oscilloscope, it is best to obtain the test signal from an audio oscillator. Although a phonograph or tuner can be used to supply the input signal, it may be harder to locate the defective stage because of the complexity of music and voice waveforms.

Shorted or leaky coupling capacitors can also cause distortion due to a shift in the operating point. Often the transistor element voltage changes are not great, so use care when making the measurements.

Most of the output stages in transistorized amplifiers operate Class AB, although they are usually referred to as Class B. A small amount of forward bias is applied to the transistors to eliminate **CROSSOVER DISTORTION.** This type of distortion occurs when one transistor cuts off before the other starts conducting. Figure 20 shows the output waveform of a push-pull stage with crossover distortion. Note the waveform distortion at the crossover point. Severe crossover distortion is shown by the waveform of Figure 21.

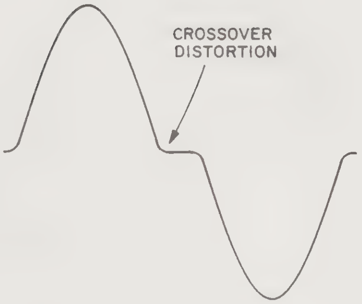


Figure 20

When you encounter a problem such as this, check the bias voltages on the output stage. Often, when a transistor fails in an output stage, enough current is drawn to alter the values of some of the bias components. It is a good idea to check the bias component values when you replace output transistors. Also make sure you replace both transistors with a matched pair when one transistor becomes defective. Mismatched transistors can also cause crossover distortion in most amplifier circuits.

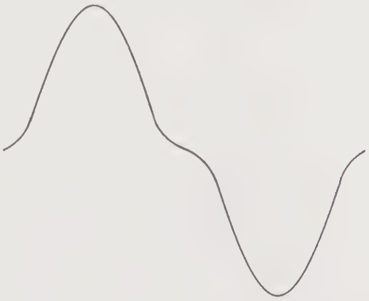


Figure 21

Circuit defects that cause changes in frequency response are also sometimes difficult to locate. Most amplifiers employ negative feedback to reduce distortion and increase frequency response. If the feedback loop were to open, distortion would increase and the frequency response would decrease. However, at the same time the circuit gain would also increase. The increase in gain would be your key to suspecting trouble in the feedback loop.

When checking for problems that affect frequency response, a sinewave signal is not very useful. Measurements at several test frequencies must be made and compared to determine any effect on frequency response. A much simpler method is to employ a square wave test signal. A square wave signal contains both high- and low-frequency components. Oscilloscope observation of the signal as it progresses through the amplifier will show any frequency response problems.

Figure 22A shows a normal square wave. If the high-frequency response of the amplifier is poor, the leading edge will be rounded, as shown in Figure 22B. To reproduce a proper leading edge, the response of the amplifier must be reasonably flat to the tenth harmonic of the square wave fundamental frequency. Thus, if a 2-kHz test signal were used, it would check the response out to 20 kHz.

Poor low-frequency response is indicated by a droop in the top and bottom of the square wave, as shown in Figure 22C. Again, a test frequency of 2 kHz can be used. Good response to 200 Hz or less is necessary to assure a flat top on a 2-kHz square wave.

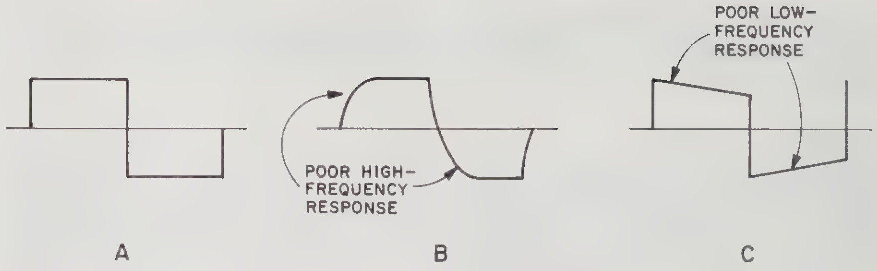


Figure 22

Several precautions should be followed when employing square wave testing. First, make sure that the output of the generator is a good square wave and that the oscilloscope itself is not introducing any distortion. Also make sure that the oscilloscope is not affecting the waveshape when it is connected to the circuit. It may be necessary to use a low-capacitance scope probe when square wave testing in high-impedance circuits.

The tone and loudness controls also affect frequency response. Make sure that these controls are at their flat positions when checking for a frequency response fault.

The components most likely to affect frequency response are coupling and bypass capacitors. An interstage or output transformer can also alter frequency response. However, with the use of direct coupling, coupling capacitors and transformers are eliminated. Distortion problems in direct-coupled circuits are often due to the dependence of one stage on another for bias.

Another problem that sometimes occurs in an amplifier is oscillation. Oscillations can occur at both low and high frequencies. The usual cause is a defective bypass capacitor or a defective component in a feedback loop. This type of a problem is sometimes difficult to pinpoint, as the whole amplifier appears to be oscillating. Shunting the power supply bypass capacitors will usually point out a defective bypass capacitor. Disconnecting the signal feedback loop will show if the problem is here. Note: Do not disconnect dc feedback loops, as this will cause a bias change.

Noise, other than power supply ripple or ac pickup, can also occur in an amplifier. This is usually produced in the low-level stages. Slight changes in the characteristics of a transistor may cause it to become noisy. You may have to select a transistor from several that are available to obtain one with a low enough noise level for a low-level stage. Resistors can also cause problems in low-level stages. Conventional carbon resistors often produce a considerable amount of noise. For this reason, deposited carbon film

The harmonic distortion meter can be used to measure the actual harmonic distortion in an amplifier.
Courtesy Heath Company

resistors are often employed in low-level stages. Always replace one of these resistors with one of the same type.

FOUR CHANNEL AMPLIFIERS

As four channel, or quadraphonic sound becomes increasingly popular, amplifiers designed for use with four sound channels are being made available. The controls and operating modes that each amplifier offers are determined primarily by which type of four channel system the amplifier manufacturer favors.

Some units contain four independent channels of amplification; and some contain only two power amplifiers, but have control facilities for all four channels to adapt available older equipment to the new formats. Strapping, or bridging circuits, are offered in some units to utilize all four power amplifiers for two channel operation until a later time when the system is expanded to four channel use. Figure 23 shows the strapping technique in block diagram form.

In the two channel mode of operation, the rear channel amplifiers are disconnected from the rear channel speakers. The front channel input signals are applied to the rear channel inputs through phase inverters. The

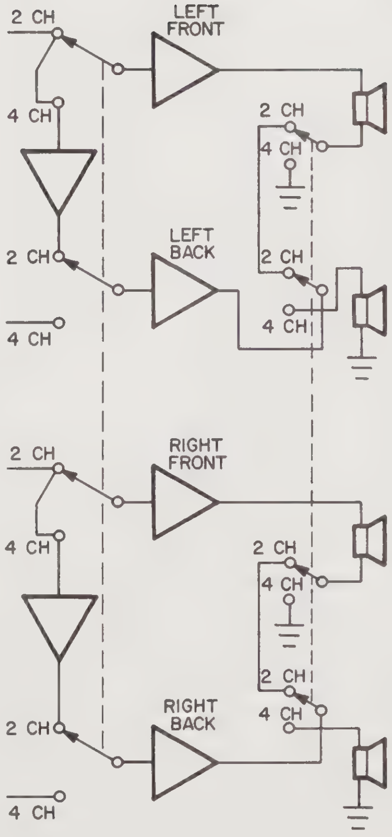


Figure 23

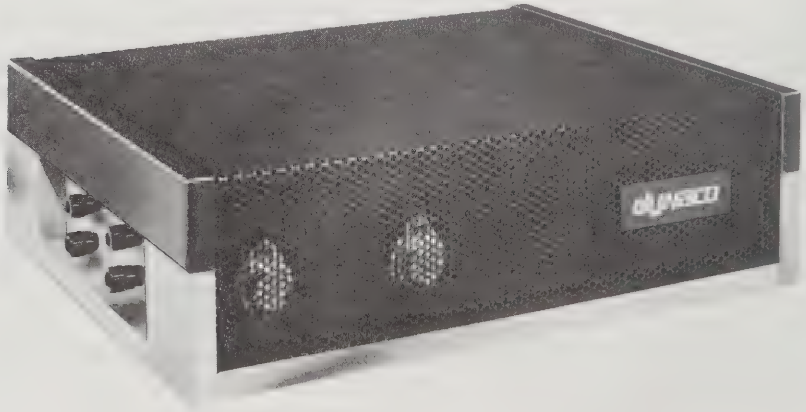
outputs of the rear channel amplifiers then go to what are normally the ground return leads of the front channel speakers. The front and rear amplifiers of the left channel therefore drive the front speaker of the left channel in what is essentially a series connection of the two amplifiers. The right channel operation, of course, is identical. This configuration provides more than double the amount of power output that each individual amplifier can provide in a conventional circuit arrangement.

SUMMARY

The most common problems encountered with low-level stages are increases in hum and noise levels. Leaky or open filter capacitors, and input stage resistors, transistors or mechanical connections can all contribute to increases in noise and hum levels.

Most high-powered audio amplifiers use quasi-complementary-symmetry output stages, although some more expensive units employ full complementary-symmetry throughout the driver and output stages. Some amplifiers use positive and negative supply voltages, which permit direct coupling to the output load for improved low-frequency response.

To protect expensive output transistors, most amplifiers utilize some sort of overload protection. This protection might be provided by a fuse, circuit breaker, or a circuit that is designed to shut itself off in the event of an output overload.



The power supply in this 120-watt stereo amplifier employs a full-wave bridge rectifier and an electronic regulator circuit.
Courtesy Dynaco, Division of Tyco

The following Practice Exercise questions cover the subjects which you have just studied. They are:

LOW-LEVEL INPUT STAGES

QUASI-COMPLEMENTARY-SYMMETRY OUTPUT STAGE

FULL COMPLEMENTARY-SYMMETRY OUTPUT STAGE

OVERLOAD PROTECTION

POWER SUPPLIES

ELECTRONIC FILTERS

PROTECTIVE CIRCUITRY

FREQUENCY RESPONSE AND DISTORTION PROBLEMS

SQUARE WAVE TESTING

FOUR CHANNEL AMPLIFIERS

22. How does the quasi-complementary-symmetry output stage eliminate the need for a driver transformer?

23. The rectifier circuit in Figure 15 is (a) half wave, (b) full wave, (c) a full-wave bridge.

24. What is the purpose of D_3 in Figure 15?

25. Complete failure of both channels indicates the trouble may be in the power supply. True or False?

26. How can a fault in one channel of a stereo amplifier make both channels inoperative?

27. Suppose that R_2 is open in the circuit of Figure 15. Describe how you would troubleshoot the circuit to locate the defect.

28. What would be the probable result if D_2 shorts in the circuit of Figure 15?

29. A defective filter capacitor in the circuit of Figure 15 would produce (a) 60-Hz hum, (b) 120-Hz hum, (c) 240-Hz hum.

30. Suppose C_4 in the circuit of Figure 15 shorts. Describe the tests you would make to arrive at the trouble.

31. What would the effect be if Q_1 would short in the circuit of Figure 16?

32. How does an unbypassed emitter resistor reduce stage gain? What is an advantage of such an arrangement?

33. What is a common cause of distortion?

34. What is crossover distortion and what is a common cause of it?

35. When one output transistor in a push-pull stage fails, it is only necessary to replace the defective one. True or False?

36. The best test signal waveshape for distortion testing is the ______________ and for frequency response testing is the ____________ ____________.

37. How is poor high- and low-frequency response indicated on a square wave test signal?

38. The components most likely to affect frequency response are coupling and bypass capacitors. True or False?

39. Why are deposited carbon resistors employed in low-level stages?

Many of the simple hi-fi/stereo amplifiers employ direct-coupled amplifiers with complementary-symmetry output stages. Due to the direct-coupled circuitry, signal tracing and signal injection may not pinpoint the trouble. In these cases, careful bias voltage measurements will usually point out the defect. When one transistor in a complementary-symmetry stage is defective, both should be replaced, as a matched pair is essential for proper circuit operation.

Troubleshooting amplifiers that employ RC and transformer coupling are a bit simpler. Signal tracing or signal injection can be used to locate the defective stage. Voltage and resistance measurements in the defective stage can be used to locate the defective component.

Most of the power supplies employed in transistorized hi-fi/stereo amplifiers are conventional full-wave circuits. Zener diodes are often used where a regulated voltage is necessary. A capacity multiplier circuit is often used to provide a large value of filter capacitance to reduce ripple.

Some power supplies are fully regulated to decrease distortion and increase low-frequency output at full power. Some of the regulator circuits also provide overload protection by shutting off the output of the power supply during overload conditions.

Four channel amplifiers are also available. Their operating features and modes of operation reflect their manufacturer's approaches to quadraphonic sound.

IMPORTANT DEFINITIONS

CAPACITY MULTIPLIER—An emitter-follower stage that provides an effective capacity equal to the transistor beta times the base circuit capacitance.

CROSSOVER DISTORTION—Distortion occurring in a push-pull stage when one transistor cuts off before the other conducts.

LOUDNESS CONTROL—A compensated volume control which provides bass and treble boost at low volume levels. Many loudness control circuits boost only the low frequencies.

PRACTICE EXERCISE SOLUTIONS

1. As long as the trouble is confined to one channel, the voltages, resistances, signal levels, etc., in the defective channel can be compared to those in the operating channel to locate the trouble.

2. False—Unless you are sure the circuit will not be damaged if operated without a load, always connect the proper value load to the amplifier under test.

3. A low-wattage soldering iron is more suitable than a soldering gun.

4. R_{10} provides feedback to stabilize the amplifier.

5. A decrease in the voltage at the emitters of Q_3 and Q_4 increases the forward bias on Q_1. The reduced Q_1 collector voltage increases the forward bias on Q_2. The reduced Q_2 collector to emitter voltage increases the voltage at the collector of Q_2 and the bases of Q_3 and Q_4. In turn, the conduction of Q_3 increases and that of Q_4 decreases to bring the voltage at the emitters back to the original value.

6. False—A temperature increase causes a decrease in the voltage drop across the diodes.

7. True

8. The high or ungrounded end of the volume control.

9. Measure the resistance, reverse the meter leads and measure the resistance again. If the diode is good you should get a low reading in one direction and a high reading in the other.

10. False—Signal injection tracing can sometimes be used. However, careful voltage measurements are often the only way in which the defective stage can be found.

11. True

12. True

13. C_2 provides negative feedback to increase the input impedance of the Q_1 stage.

14. (c) top.

15. At the center position, the treble control has no effect on the high-frequency response and the control is at its "FLAT" position.

16. (c) bottom.

PRACTICE EXERCISE SOLUTIONS (Continued)

17. False—Both the low and high frequencies must be boosted to compensate for the drop-off in the ear's response.

18. R_{13} and the associated components boost the response at low frequencies to compensate for the large drop-off in the ear's response at low frequencies.

19. (c) AB.

20. The amplifier would be inoperative on all inputs. Substituting a test signal at the output stage and working towards Q_1 would show the amplifier functioning normally until the signal is injected at the emitter of Q_1. With the signal injected at the R_5 side of C_3, the normal output would be obtained. Substituting a new capacitor for C_3 would restore operation.

21. True

22. By using a PNP-NPN (complementary-symmetry) driver stage, the driver transformer is eliminated.

23. (b) full wave.

24. D_3 is a zener diode that provides a regulated supply voltage at output E_3.

25. True

26. A fault such as a short in one channel can reduce the power supply output voltage to the point where the other channel becomes inoperative.

27. Initial checks of the fuse and primary circuit would show no defect. Voltage measurements at E_1 and E_2 would show normal or slightly higher than normal readings. The voltage at E_3 would be zero. An ohmmeter check would show R_2 open.

28. The fuse would probably open.

29. (b) 120-Hz hum.

30. Initial tests would show the primary circuit of T_1 to be all right. A voltage check at E_1 would show normal or slightly lower than normal voltage. R_1 would probably show evidence of overheating and a voltage check at E_2 would show zero volts. An ohmmeter check of C_4 would show that it is shorted.

31. With Q_1 shorted the capacity multiplication would not occur and the ripple would increase causing hum in the amplifier.

32. The unbypassed emitter introduces negative feedback which reduces stage

PRACTICE EXERCISE SOLUTIONS (Continued)

gain. An advantage of negative feedback is a reduction in distortion and increased frequency response.

33. A shift in the operating point due to a shift in bias.

34. Crossover distortion is produced in a push-pull stage when one transistor cuts off before the other conducts. This type of distortion is often caused by a shift in the bias voltages on the output transistors.

35. False—Both transistors should be replaced with a matched pair.

36. sinewave; square wave

37. Poor high-frequency response is indicated by a rounding of the leading edges while poor low-frequency response is indicated by a droop in the waveform tops and bottoms.

38. True

39. Deposited carbon resistors produce lower noise than the conventional composition type.

DE VRY INSTITUTE OF TECHNOLOGY
4141 BELMONT AVENUE, CHICAGO, ILLINOIS 60641

ONE OF THE
BELL & HOWELL SCHOOLS

7535A
EXAMINATION CHECK SHEET

7535A

1. A - WHEN TESTING AN AUDIO POWER AMPLIFIER -- NEVER OPERATE IT WITHOUT A LOAD.
Many circuits can be damaged if operated without a load. A resistor of correct value and wattage may be substituted for the speaker.

2. A - THE Q_3Q_4 STAGE IN THE CIRCUIT OF FIGURE 1 OPERATES CLASS -- AB.
Although the stage actually operates Class AB, it is often referred to as a Class B amplifier.

3. B - IN A CIRCUIT LIKE THAT OF FIGURE 1, THE TRANSISTOR OR TRANSISTORS MOST LIKELY TO FAIL ARE -- Q_3 AND Q_4.
Due to the voltage and current levels encountered, the output transistors are most subject to failure.

4. A - A SHIFT IN BIAS ON THE Q_1 STAGE OF FIGURE 1 WILL AFFECT THE BIAS ON -- ALL THE STAGES.
Due to the direct coupling, a shift in the bias on one stage will affect the bias on the other stages.

5. B - IF C_4 IN THE CIRCUIT OF FIGURE 5 OPENS -- NO BASS ATTENUATION WILL OCCUR.
As shown in Figure 7C, C_4 controls bass attenuation.

6. C - SUPPOSE THE AMPLIFIER OF FIGURE 5 HAS NO OUTPUT. INJECTING A TEST SIGNAL AT THE LOUDNESS CONTROL PRODUCES AN OUTPUT. THE TROUBLE COULD BE -- IN THE Q_1 STAGE.
All the circuits following the loudness control are operating and the trouble must be ahead of the loudness control.

7. C - WITH RESPECT TO RIAA EQUALIZATION ON PLAYBACK -- THE AMPLIFIER MUST ATTENUATE THE HIGH FREQUENCIES AND BOOST THE LOW FREQUENCIES.
This is the opposite of the recording equalization, and it is used to restore flat response to the recorded signal.

8. D - WHAT WILL BE THE EFFECT IF THE BIAS ON A COMMON-EMITTER PNP TRANSISTOR STAGE INCREASES TOWARDS SATURATION? -- CLIPPING ON THE POSITIVE ALTERNATION OF THE OUTPUT.
With increased bias the circuit will clip the negative alternation of the input resulting in clipping of the positive alternation of the output.

9. D - WHAT COULD BE THE EFFECT IF C_1 OPENS IN THE CIRCUIT OF FIGURE 15? -- FAILURE OF D_1.
With C_1 open, the circuit would operate normally. However, a line transient could cause D_1 to short since C_1 protects D_1 against transients during the time it is reverse biased.

10. C - A SQUARE WAVE WITH A ROUNDED LEADING EDGE SHOWS -- POOR HIGH-FREQUENCY RESPONSE.
The leading edge indicates the high-frequency response. A rounded leading edge indicates poor high-frequency response.

QUESTIONS

IMPORTANT—These instructions **MUST** be accurately followed to avoid loss, or errors in grading.

Indicate your answer on this sheet by filling in the box for the most correct answer to each question, as illustrated in the example below.

When all questions have been answered, place the answer card in the proper position to line up the boxes on the card with the boxes on the sheet.

Next, copy the complete lesson code into the space provided on the card, and fill in the answer boxes to correspond with those previously filled in on this sheet.

Before mailing, be certain your correct student number, name and address appear on the card.

LESSON CODE
7535A

Example: The earth is a
A ☐
B ☐
C ☐
D ■
(A) meteor. (B) comet. (C) star. (D) planet.

1. A ☒ B ☐ C ☐ D ☐

When testing an audio power amplifier
(A) never operate it without a load. (B) it is not necessary to unplug the unit while making solder connections. (C) short the speaker terminals. (D) no load is needed at the speaker terminals.

2. A ☒ B ☐ C ☐ D ☐

The Q_3Q_4 stage in the circuit of Figure 1 operates Class
(A) AB. (B) A. (C) C. (D) B.

3. A ☐ B ☒ C ☐ D ☐

In a circuit like that of Figure 1, the transistor or transistors most likely to fail are
(A) Q_1. (B) Q_3 and Q_4. (C) Q_2. (D) Q_1 and Q_2.

4. A ☒ B ☐ C ☐ D ☐

A shift in bias on the Q_1 stage of Figure 1 will affect the bias on
(A) all the stages. (B) Q_1 only. (C) Q_1 and Q_2. (D) only Q_2.

5. A ☐ B ☒ C ☐ D ☐

If C_4 in the circuit of Figure 5 opens
(A) no bass boost will occur. (B) no bass attenuation will occur. (C) no treble attenuation will occur. (D) no affect will be noticed.

6. A ☐ B ☐ C ☒ D ☐

Suppose that the amplifier of Figure 5 has no output. Injecting a test signal at the loudness control produces an output. The trouble could be
(A) in the power supply. (B) in the Q_3 driver stage. (C) in the Q_1 stage. (D) in the Q_4Q_5 output stage.

7. A ☐ B ☐ C ☒ D ☐

With respect to RIAA equalization on playback
(A) a magnetic pickup provides self equalization. (B) the amplifier must boost both the low and high frequencies. (C) the amplifier must attenuate the high frequencies and boost the low frequencies. (D) the amplifier must attenuate both the low and high frequencies.

8. A ☐ B ☐ C ☐ D ☒

What will be the effect if the bias on a common-emitter PNP transistor stage increases towards saturation?
(A) Clipping on the negative alternation of the output. (B) Clipping on the positive alternation of the input. (C) Increased gain. (D) Clipping on the positive alternation of the output.

9. A ☐ B ☒ C ☐ D ☐

What could be the effect if C_1 opens in the circuit of Figure 15?
(A) 60-Hz ripple. (B) 120-Hz ripple. (C) Reduced output. (D) Failure of D_1.

10. A ☐ B ☐ C ☒ D ☐

A square wave with a rounded leading edge shows
(A) poor low-frequency response. (B) good high-frequency response. (C) poor high-frequency response. (D) good low- and high-frequency response.

SERVICING RECORD CHANGERS AND TURNTABLES

7540

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PRINTED IN USA

This special pickup arm assembly moves in a straight line across the record and eliminates the tracking error caused by a conventional pickup arm.
Courtesy Rabco

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Performance Troubleshooting .... Page 23

They do me wrong who say I come no more,
When once I knock and fail to find you in;
For every day I stand outside your door,
And bid you wake, and rise to fight to win.
—Judge Walter Malone

SERVICING RECORD CHANGERS AND TURNTABLES

Most home entertainment music systems employ a RECORD CHANGER which will automatically play a stack of records and shut off after the last record. Some professional music systems employ a TURNTABLE which contains no automatic record changing mechanism. Records are played on the turntable one at a time. An **AUTOMATIC TURNTABLE** is a combination of the automatic features of the record changer and the performance of a turntable.

Both the turntable and record changer are mechanical devices and the troubles associated with them are usually mechanical. Worn, bent or broken parts, slippage in belts and pulleys, defective drive pulleys and worn bearings are all common troubles. Because the only electrical components in the units are a motor and some switches, servicing the electrical system is quite simple.

The mechanical systems employed in turntables and changers in many respects are similar and at the same time are different. This lesson will present some of the basic mechanical systems. Once you understand the operation of one unit the others will be no problem. The simplest servicing approach is to observe the operation of the unit to determine what function

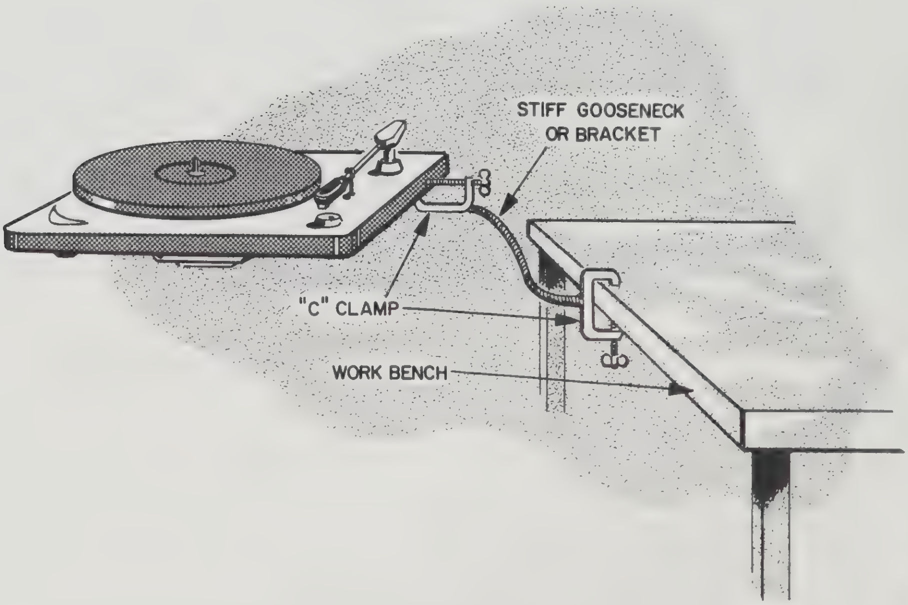


Figure 1

is not operating properly. Most units can be operated at slow speed by rotating the turntable with your hand. In this way you can better observe the operation and determine the trouble. Service literature provided by the manufacturer and other companies usually gives a step by step operating sequence which is a great aid in determining the cause of trouble.

If you do a lot of record changer and turntable repair, a test jig to hold the unit on your bench is helpful. Some of the commercial chassis holding jigs or vises can be used. The unit should be elevated above your bench so you can observe the operation of the mechanism without tipping it. Many units will not operate properly if tilted too far. The jig shown in Figure 1 allows complete access to all parts of the turntable, while allowing it to remain level.

DRIVE SYSTEMS

Many turntables and record changers employ a rim drive system like that shown in Figure 2. A rubber idler wheel presses against the inside rim of the turntable and motor pulley. Speed changing is accomplished by moving the idler wheel up and down the stepped motor pulley. The diameters of the motor pulley, idler wheel and turntable are chosen to provide the standard speeds of $16^{2}/_{3}$, $33^{1}/_{3}$, 45 and 78 rpm. The slowest speed is on the smallest step of the motor pulley and vice versa. The turntable rotates on a ball thrust bearing or some other low friction bearing.

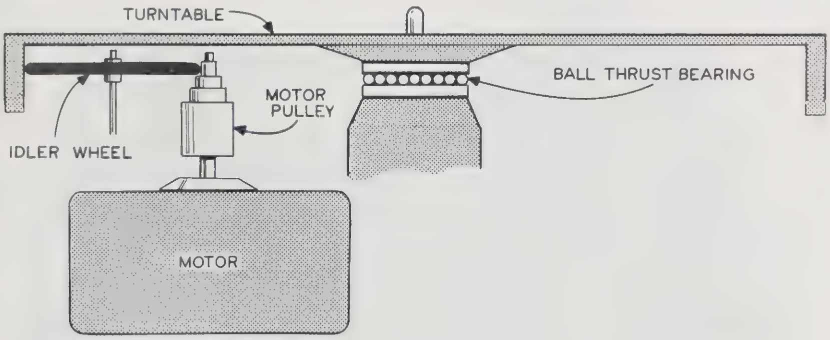


Figure 2

To change speed, the idler wheel is moved up and down the stepped motor pulley. Figure 3 shows a common method of moving the idler wheel. The idler wheel is attached to a rocker arm. A pin on the rocker arm rides in a stepped slot in the speed selector cam. As the speed selector lever rotates the cam, the rocker arm moves the idler arm up and down. To prevent flat spots on the rubber idler wheel, the unit is arranged so that the idler wheel is

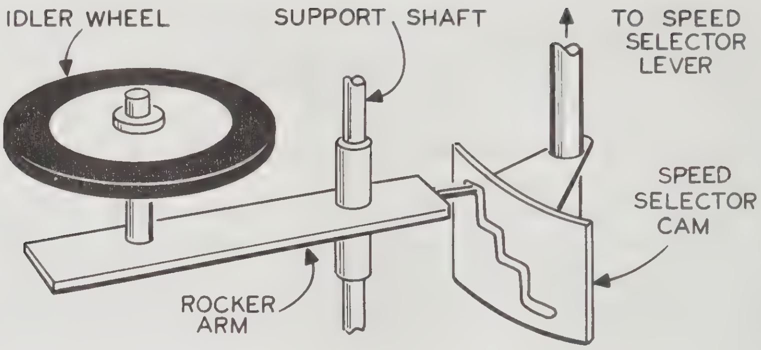


Figure 3

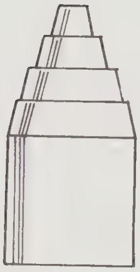


Figure 4

moved away from both the motor pulley and turntable rim when the unit is turned off.

The drive system shown in Figure 2 provides four specific speeds. There is no provision for speed adjustment. Because of manufacturing tolerances, wear or low line voltage, the speed may not be exact. Some units provide a fine speed adjustment by using a tapered stepped motor pulley like that shown in Figure 4. A knob or lever connected to the rocker arm moves the idler wheel up and down the tapered portion of the step to provide fine speed adjustment. A speed adjustment of 6% to 10% is typical.

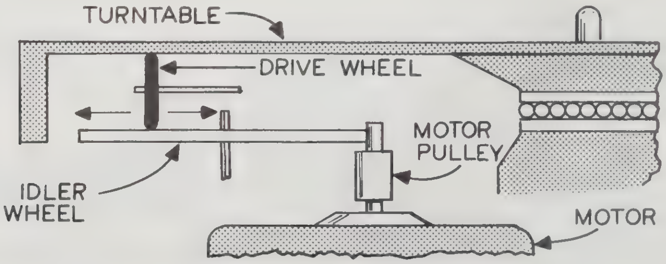


Figure 5

Another variable speed drive system is shown in Figure 5. Here the speed is "infinitely" variable from below the minimum speed, $16^{2}/_{3}$ rpm, to above the maximum speed, 78 rpm. The motor pulley drives a large idler wheel. A drive wheel contacts both the turntable and the idler wheel. Moving the drive wheel back and forth varies the speed. Moving it towards the hub of the idler wheel decreases the speed and vice versa. The lever or knob that moves the drive wheel has a detent or notch at the positions which provide the four common speeds. The speed control can then be moved back and forth around the notch or detent to vary the speed slightly.

Drive System Troubleshooting

There are several types of troubles that are common to most types of turntable and record changer drive systems. The most common is slippage in the drive system. This causes speed variations or "WOW," and in some situations the unit may stop when the change cycle occurs. The rubber drive and idler wheels wear and become slick. Also, the inside of the turntable rim and motor pulley may become polished with use to a point where slippage occurs. Normal operation can often be restored by cleaning the drive system components with alcohol or a suitable solvent. It may be necessary to replace the idler wheel if it is badly worn. There are also some "nonslip" fluids that may be applied to the drive system components to increase friction. Be careful when oiling the pulley shafts, etc., so that none of the lubricant gets on the drive surfaces or slippage will occur.

If slippage occurs during the change cycle, be sure the automatic mechanism is not binding. You can run it through a cycle by hand to determine if change mechanism binding is occurring.

Another common problem is flat spots on the drive or idler wheels. This can cause a thumping sound or rumble in the audio output. Most units employ a mechanism that moves the drive and idler wheels apart when the unit is turned off. If the mechanism is not operated properly, or if it is out of

The small size of solid-state circuitry permits a complete AM-FM/FM Stereo receiver and 60-watt amplifier to be built into the base of this automatic turntable.
Courtesy Harmon Kardon, Inc.

adjustment, flat spots can develop. The only cure is to replace the defective part.

Flat spots on parts of the drive system other than the idler wheel can also cause a thumping sound in the unit. This vibration can be transmitted to the pickup and appear in the amplifier output. The resultant sound often takes the form of a low pitch **RUMBLE.** Actually, any irregularities in the drive system will cause rumble. The turntable thrust bearing and motor bearings are a common cause of rumble. Replacement of the worn parts is the only sure cure.

Other drive system troubles, such as failure to operate at one speed, binding, etc., can be traced to bent or broken parts. A good visual inspection will often locate these troubles. Grease can also prevent proper operation by collecting dirt or wearing out. A thorough cleaning and relubrication will cure this trouble. Do not over lubricate, as this can cause an accumulation of dirt. Too much grease or oil is as bad as not enough.

ELECTRICAL SYSTEMS

The electrical system associated with a turntable or record changer is quite simple. Figure 6 shows a typical circuit. The drive motor is controlled by switch S_1. This switch is generally operated by the speed change lever. On some turntables, the switch is turned off by an automatic mechanism when the record is completed. On changers, the switch is automatically turned off after the last record has been played. R_1 and C_1, connected across the switch, form a "pop filter" to eliminate noise in the amplifier when the motor is turned on or off. Four-pole induction motors are quite common on record changers. Professional turntables and some changers employ synchronous motors which have greater speed accuracy and regulation.

The outputs from the pickup unit go through a muting switch. The muting switch is linked to the mechanism so that the output is shorted during any

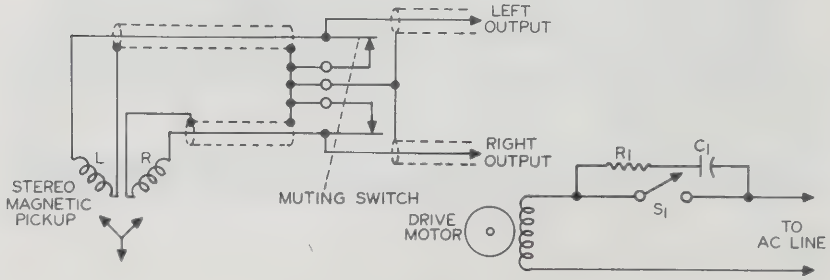


Figure 6

automatic operation, such as during a record change, etc. The switch opens when the pickup is on the lead-in groove of the record.

The platter and tone arm share a common ground. This ground is not connected within the turntable to the cartridge ground, but is instead connected to the amplifier's ground terminal. This arrangement prevents a ground loop from occurring.

Troubles in the electrical system are usually easy to find. The drive system contains only a motor and a switch. An ohmmeter can be used to check each of these components. A defective motor or switch is generally replaced, except if the trouble is only a broken wire, bent contact, etc. When replacing a motor, an exact replacement should be obtained. Many turntables and record changers with magnetic pickup units employ a motor with shielding to reduce the external radiated field. Although a motor of a different type may work, its field may cause hum pickup by the cartridge.

On most units, the drive motor is shock mounted on rubber grommets. A metal strap is used to ground the motor frame to the frame of the changer or turntable. If this strap is broken, noise or hum may be introduced into the pickup.

Depending upon the unit, the output from the pickup may be terminated in a set of jacks or in a couple of leads with plugs on the ends. The pickup unit can be checked with a high gain signal tracer or oscilloscope. More often than not, the pickup stylus will need replacement rather than the pickup cartridge itself. Stylus replacement, pressure adjustment, etc., will be covered later in this lesson.

A defect in the muting switch could cause no output, or the muting may not occur. You can use your ohmmeter to check the switch. To prevent damage to the cartridge or false indications, it is a good idea to disconnect the cartridge. You can do this by pulling the connecting pins, or if the unit employs a plug-in head, by removing the head. If the switch itself is all right, it may be necessary to adjust the activating mechanism.

The leads which connect to the pickup are made of very fine shielded wire. On occasion, they may break from continued flexing and need replacement. Make sure the replacement wire is as flexible as the original. A stiffer wire could cause pickup tracking problems. Whenever hum or noise is present, make sure the shields on these wires are not broken. In some stereo systems, the shields on the output leads must be insulated from each other and connected together only at the amplifier input. If they are connected together at the pickup and the amplifier, a ground loop can occur and result in hum and noise.

RECORD CHANGERS

Record changers are very popular in home entertainment music systems. A stack of records is placed on the changer and the changer plays them one after another. At the end of the last record, the changer shuts off. Most changers also have a feature that allows records to be played manually, one at a time. This is the same type of operation obtained on a turntable which does not contain an automatic record change mechanism. This type of unit is generally of very high quality and is found in professional music systems. The AUTOMATIC TURNTABLE is a combination of both types. It contains an automatic record change mechanism which can be mechanically disabled so that the unit can function as a manual turntable.

Carefully follow the manufacturer's instructions on lubrication. The old method, "lubricate anything that moves," can be disastrous. Some parts like trip mechanisms depend upon friction for proper operation. Excess lubrication should also be avoided. This can cause an accumulation of dirt and result in improper operation.

This automatic turntable can function as a manual play turntable or record changer.
Courtesy Garrard Div., British Industries Corp.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

DRIVE SYSTEMS

DRIVE SYSTEM TROUBLESHOOTING

ELECTRICAL SYSTEMS

1. What is the best way to check out the operation of a record changer?

2. Explain how a change in speed is obtained with the drive system of Figures 2 and 3.

3. Which step on the motor pulley in Figure 2 would provide the lowest speed?

4. How can the speed be "varied" with a stepped motor pulley arrangement?

5. In Figure 5, moving the drive wheel towards the hub on the idler wheel (a) increases the speed, (b) decreases the speed.

6. A common cause of slippage in a record changer drive system is a defective (a) idler wheel, (b) drive motor, (c) turntable bearing.

7. What is the result of flat spots on the idler wheel?

8. List some common causes of rumble.

9. What is a danger of over lubrication?

10. What is the purpose of R_1 and C_1 in Figure 6?

11. The motor that provides the most constant speed is the (a) induction motor, (b) synchronous motor.

12. Why are some turntable motors shielded?

13. It is usually necessary to replace the pickup stylus more often than the pickup. True or False?

There are several types of mechanical arrangements that are common to most record changers and automatic turntables. Familiarity with these arrangements will enable you to troubleshoot the automatic mechanisms, regardless of the type.

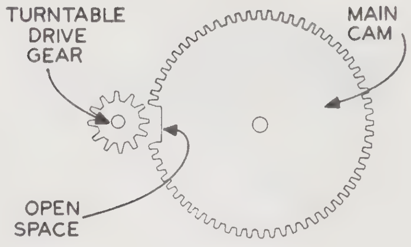


Figure 7

Clutches

The operation of the record change mechanism is generally controlled by a clutch. This clutch is tripped when the reject lever is operated or when the pickup arm reaches the lead-out grooves in the record. The clutch drives a cam, which moves various levers to position the pickup arm and drop the next record on the turntable.

Figure 7 shows one of the most common clutch arrangements. The small drive gear is located on the hub of the turntable, as shown in Figure 8. The main cam has an open space in the gear teeth around its circumference. In the rest or null position, the turntable drive gear can rotate without moving the main cam.

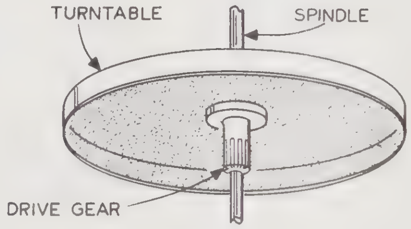


Figure 8

A trip pin is located on the main cam, as shown in Figure 9A. In the rest or null position, it does not contact any of the teeth on the drive gear. When the trip is moved outward, as shown in Figure 9B, it contacts the teeth on the drive gear. As the drive gear rotates, it pushes the trip pin and thus moves the main cam enough that the drive gear engages the teeth on the main cam. The main cam rotates about 360°, operating the automatic mechanism. When the open spot is reached, rotation of the main cam stops. This type of clutch is sometimes referred to as a "mutilated clutch."

Cams

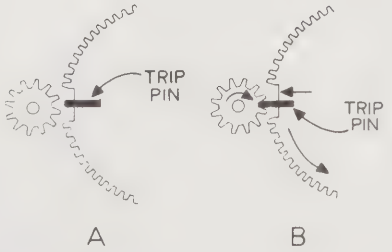


Figure 9

To produce the desired mechanical movements from rotation of the main cam, slots and raised cam surfaces are machined on the main cam. Figure 10A shows how a raised cam surface can produce an up and down motion as needed for raising and lowering the pickup arm. A back and forth motion is produced with an eccentric groove, as shown in Figure 10B. This type of motion is needed to move the pickup arm horizontally.

In summary, the mechanical motions of the changer mechanism are initiated when the main cam clutch is tripped. Raised surfaces and eccentric slots develop the mechanical movements necessary to drop the next record and position the pickup arm.

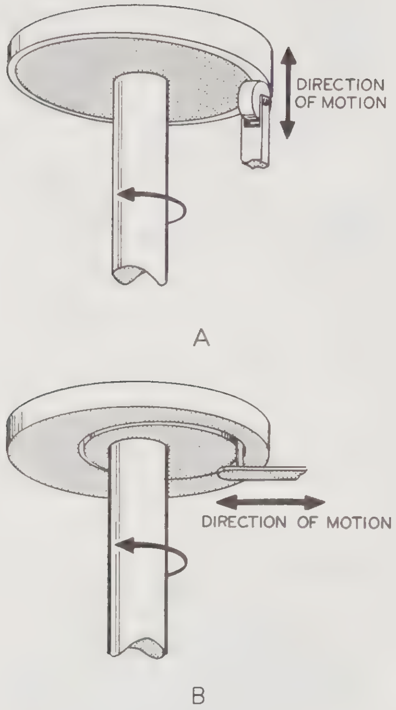


Figure 10

Trip Mechanisms

Many different types of mechanisms are used to trip the main cam clutch. Figure 11 shows a typical arrangement. The clutch is tripped when the clutch lever contacts the dog on the turntable drive gear, as shown in Figure 11B. This action rotates the main cam far enough so that it engages the turntable drive gear, as shown in Figure 11C.

The actuating arm is connected to the pickup arm. As the pickup arm moves towards the center of the record, it pushes the friction plate and the clutch lever towards the turntable drive gear dog. The friction plate moves the clutch lever by friction. Pickup arm movement from groove to groove is quite small. As a result, the clutch lever moves out towards the turntable drive gear dog a small amount and is pushed back on each revolution. This is shown in Figure 11A.

The lead-out grooves at the end of the record produce a large amount of pickup arm movement. This pushes the clutch lever out far enough so that it engages the turntable drive gear dog fully, rotating the main cam enough to engage it as shown in Figure 11C.

This type of trip mechanism is often referred to as a "velocity trip" because it depends upon the rapid movement of the pickup arm in the lead-out groove to trip the clutch. Most record changers use this type of mechanism to operate the record change mechanism when a record is finished. However, the exact mechanical arrangement may differ from one unit to another.

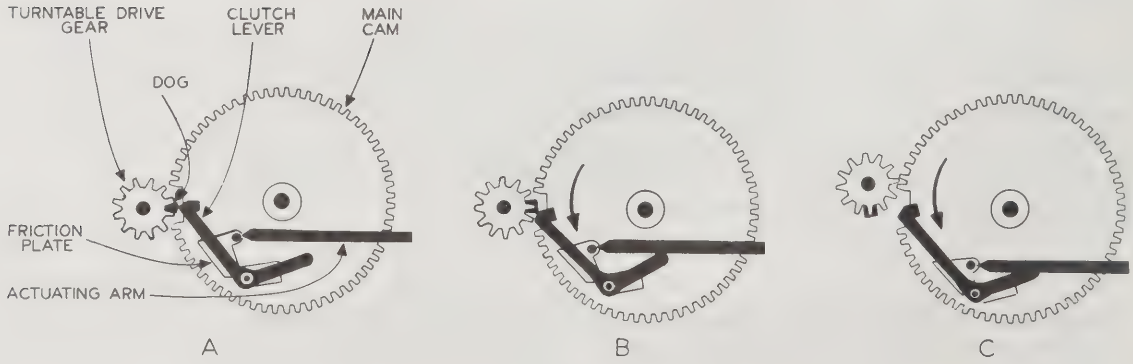


Figure 11

Record Drop Mechanisms

As with most of the other mechanisms, the record drop mechanism differs from one unit to another and yet they all have some similarities. Figure 12 shows one common arrangement. A specially designed spindle holds the record level. A mechanism within the spindle drops one record at a time to the turntable surface.

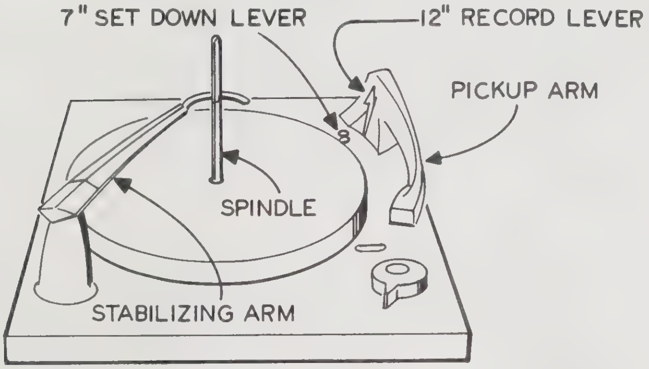


Figure 12

Figure 13 shows one type of spindle. As shown in Figure 13A, a shelf on the spindle holds the stack of records. An eccentric section of the spindle provides the record drop action. With the eccentric section in the position shown in Figure 13B, the records are supported on the shelf in the spindle. The eccentric is the thickness of a record, and when it rotates to the position in Figure 13C, it drops the bottom record to the turntable while holding the others.

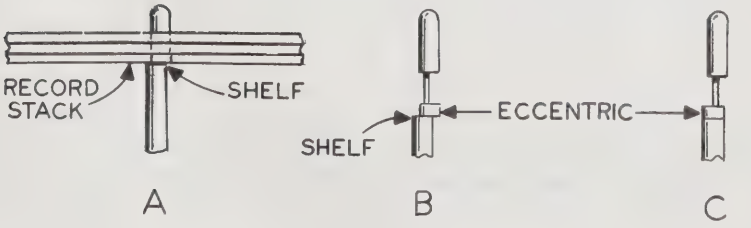


Figure 13

Another spindle arrangement is shown in Figure 14. Again, the record stack is held on the shelf of the spindle. When the pusher shaft is moved upward, it forces the record pusher to the left, moving the bottom record to a point past

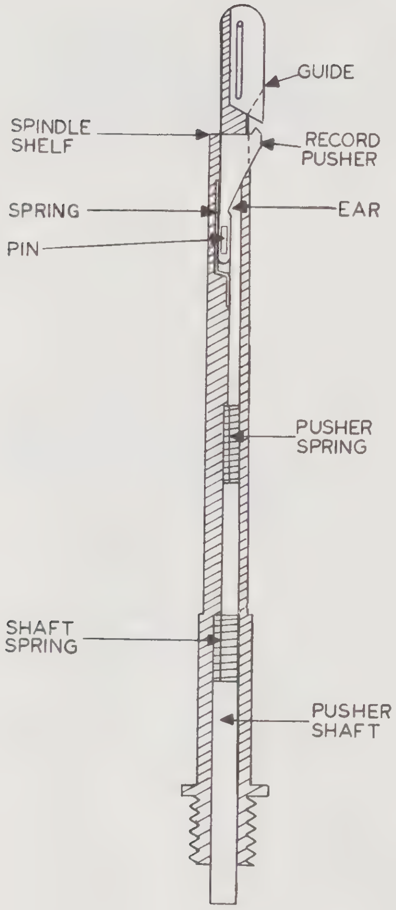


Figure 14

the shelf where it will drop to the turntable surface. The guide holds the next to the bottom record in place.

Many record changers employ a mechanism that determines the size of the record and adjusts the set down point of the pickup arm. In addition, some units change speed automatically so 7″, 45 RPM; 10″, 78 RPM; and 12″, 33¹/₃ RPM records can be played automatically. The mechanism is controlled by levers that determine the record size. Figure 12 shows a typical arrangement. A lever on the pickup arm support is moved towards the turntable during the change cycle. A 12″ record will touch it when it drops and set the mechanism accordingly. A 10″ record will not strike the lever and the mechanism will set for a 10″ record. The 7″ records can be played but not intermixed with the 10″ and 12″ records. Another lever is located near the rim of the turntable. It moves upward on the change cycle. With a 7″ record, this lever will move upward, beyond the turntable surface and set the mechanism for a 7″ record.

Besides stabilizing the stack of records, the stabilizing arm serves to shut off the changer after the last record has played. When the last record drops to the turntable surface, the stabilizing arm drops down. As the pickup arm moves into the lead-out grooves, it trips the clutch on the main cam. The dropped stabilizing arm then trips the mechanism to return the pickup arm to the rest position and shut off the drive motor.

A COMPLETE RECORD CHANGER

To further investigate the operation of record changers, let's examine the operation of a complete record changer. Figure 15 shows the mechanism of a typical unit. This particular unit is of the automatic turntable variety. That is, it can operate as a manual turntable or automatic record changer. No provisions are made for automatic selection of record size or speed. These are selected manually. The automatic operation consists of playing a stack of records and then shutting off after the last record.

Operation begins when the start button is pushed. This moves the switch lever, which closes the power switch and brings the idler wheel in contact with the turntable rim and motor pulley. The speed selector cam moves the rocker arm up or down, placing the idler wheel on the proper step of the motor pulley.

The start button also moves the start lever towards the main cam. This trips the main cam clutch, causing the main cam to rotate. Rotation of the main cam causes the cam rocker to push up on the spindle and drop a record to the turntable surface. The main lever, following the groove in the main cam, lifts

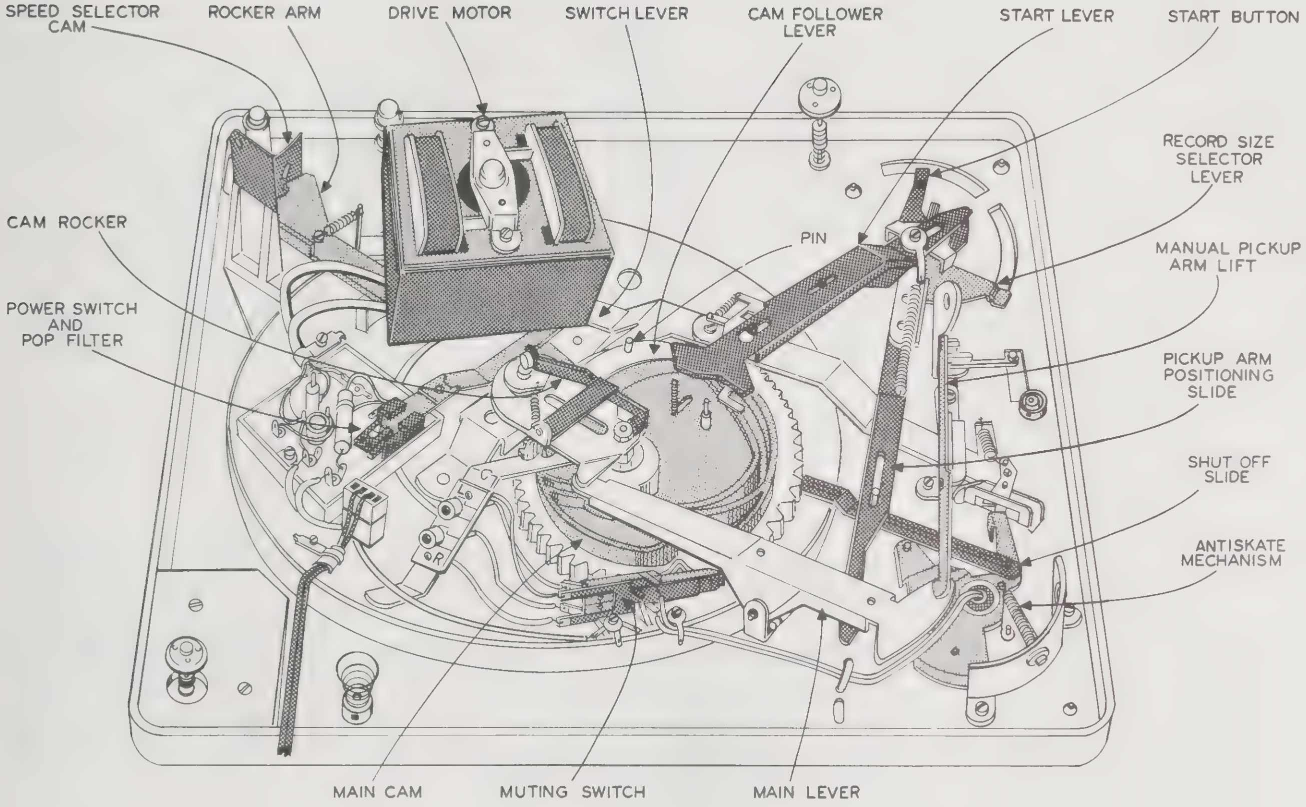


Figure 15

the pickup arm and moves it towards the record. The pickup arm positioning slide determines the set down point for the pickup arm. The record size selector lever determines the position of the pickup arm positioning slide. As the main cam completes its cycle, a pin moves the start lever back to its rest position and the mechanism returns to the rest position as the record is played. A depression in the side of the main cam opens the muting switch, removing the short on the pickup output. The muting switch shorts the pickup output during the change cycle to prevent pickup of change cycle noise.

When the pickup stylus enters the lead-out groove on the record, the shutoff lever trips the main cam clutch, starting another change cycle. This unit employs the spindle itself to determine when the last record has been played.

The spindle is spring loaded and when the last record has dropped, it moves upward slightly. This causes the end of the change lever to engage the pins on the cam follower. On a normal change cycle, the cam follower lever shown in Figure 16A is in a position that forces the pin on the main lever to

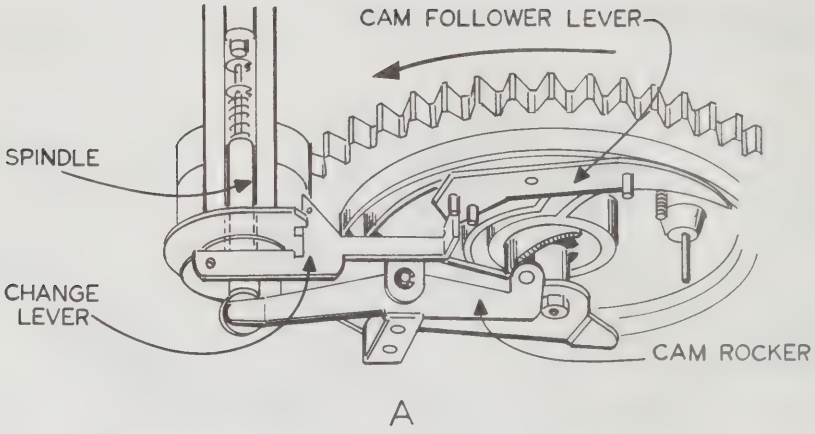


Figure 16

follow the inner slot on the main cam. When the change cycle is initiated after the last record has been played, the change lever is dropped into the two pins on the cam follower lever, as shown in Figure 16B. This causes the main lever to follow the outside slot in the main cam and hold the pickup arm over the rest position. With the pickup arm held in the rest position during the change cycle, the switch lever is tripped into the off position. This removes power from the motor and disengages the idler wheel from the turntable rim and the motor pulley.

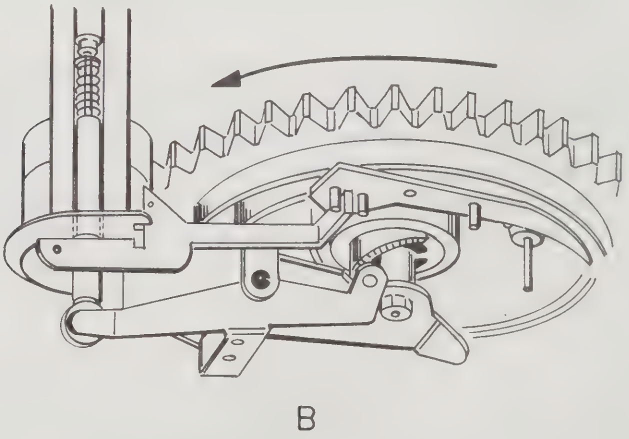


Figure 16

Several other features are included on the unit of Figure 15. When the unit is set for manual operation, the pickup arm can be raised and lowered with an arm lift lever. This permits accurate cueing as well as protecting the pickup stylus. The antiskate mechanism provides a tension on the pickup arm to prevent it from **SKATING** across the record to the center of the turntable.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

- RECORD CHANGERS
  - CLUTCHES
  - CAMS
  - TRIP MECHANISMS
  - RECORD DROP MECHANISMS
- A COMPLETE RECORD CHANGER

14. What is the difference between a record changer and a turntable?

15. When lubricating a changer, lubricate every moving part. True or False?

16. Explain the operation of the clutch arrangement of Figure 7.

17. How does the main cam produce the mechanical motions necessary for the changer operation?

18. Explain the operation of the trip mechanism of Figure 11.

19. Would you lubricate the friction plate and clutch lever assembly?

20. Explain the operation of the spindle arrangement of Figure 13.

21. What would be the result of a bent spindle on a recorder changer?

22. What action occurs to determine when a 10″ record is on the turntable in Figure 12?

23. The device on the changer of Figure 12 that shuts off the unit after the last record is played is the (a) 7″ shut down lever, (b) 12″ record lever, (c) stabilizing arm.

24. How is the clutch on the main cam tripped in Figure 15?

25. The unit of Figure 15 automatically determines the record size. True or False?

26. What is the function of the cam follower lever on the unit of Figure 15?

27. On the change cycle after the last record has been played on the record changer shown in Figure 15, the pin in the main lever follows the (a) inside slot in the main cam, (b) outside slot in the main cam.

Troubleshooting Procedures

To illustrate the servicing procedure for a record changer, let's assume some typical troubles for the unit shown in Figure 15 and examine the cause and correction.

Pickup arm does not set down properly.

> The pickup arm positioning slide assembly is misadjusted or bent.—An eccentric screw located on the positioning slide assembly is used to adjust the set down location. This screw is accessible through a hole in the top of the unit. A 7″ record is placed on the unit and the screw is turned until the pickup arm sets the stylus about $^1/_{16}$″ inside from the outer edge of the record. The 7″ adjustment sets both the 10″ and 12″ set down locations.

Stylus does not track playing groove of record.

> Worn stylus or incorrect stylus pressure.—The condition of the stylus can be checked with a stylus inspection microscope. A normal stylus will have the conical shape shown in Figure 17A. Normal wear will produce small flat spots as shown in Figure 17B. Excessive wear will produce a chisel point. This not only produces tracking problems, but will ruin a record. Wear is greater when playing stereo recordings because of the complex

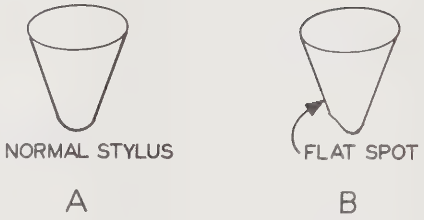


Figure 17

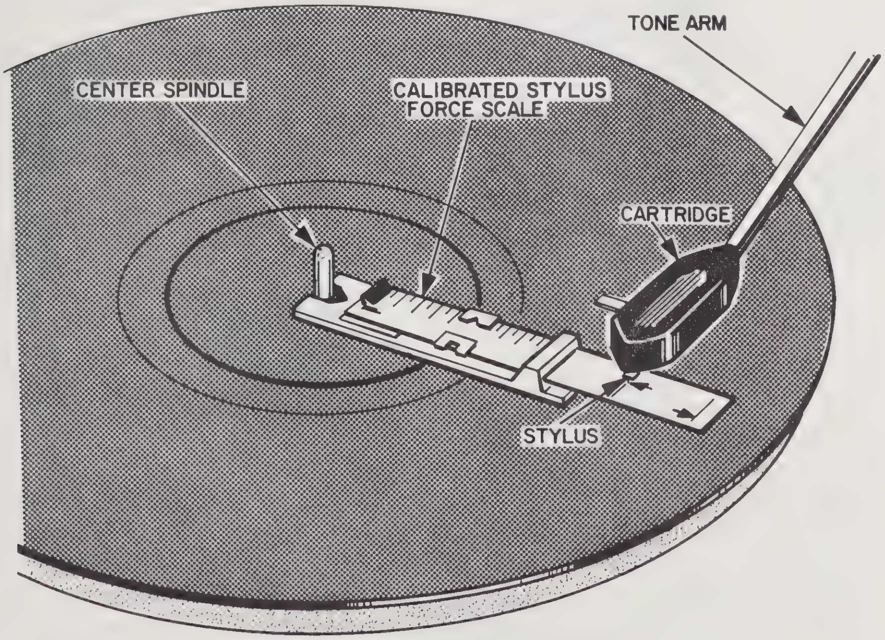


Figure 18

movements involved, and the stylus should be replaced more often. Many styli used for stereo recordings have an eliptical shape for improved tracking. Use care when replacing the stylus as excessive pressure can damage the pickup and/or stylus.

Stylus pressure is set with the aid of a stylus pressure gauge. Figure 18 shows a common scale type. The stylus pressure is generally set by adjusting the tension on a spring. Set the pressure exactly. Too low a pressure will cause tracking problems, and too high a pressure will cause excessive stylus and record wear. Figure 19 shows a typical pickup arm. To adjust the stylus pressure, the spring located under the arm is set to zero and the counter balance set to balance out the pickup arm. Then, the pressure spring is adjusted for the desired stylus pressure adjustment (as recommended by the cartridge manufacturer). This procedure is known as **DYNAMIC BALANCING.** The pickup height adjustment screw sets how high the pickup arm moves on a change cycle.

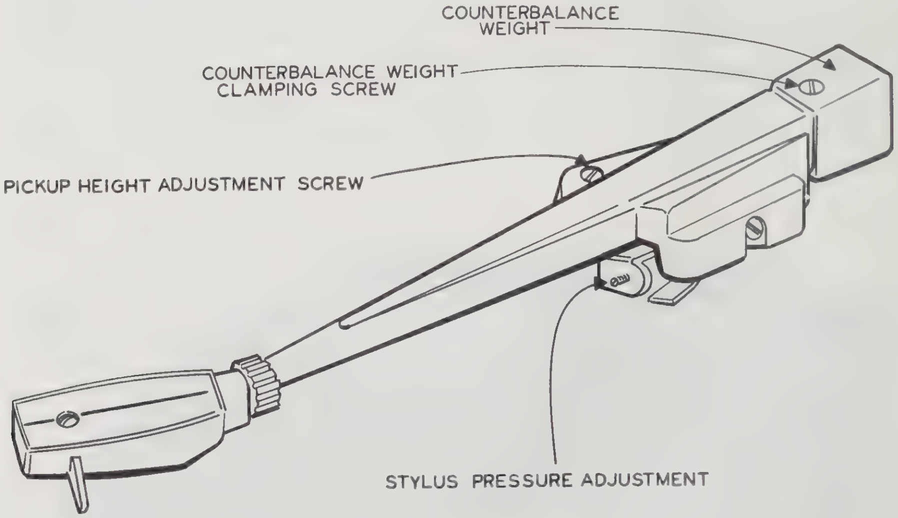

COUNTERBALANCE WEIGHT
COUNTERBALANCE WEIGHT CLAMPING SCREW
PICKUP HEIGHT ADJUSTMENT SCREW
STYLUS PRESSURE ADJUSTMENT

Figure 19

Speed variation.

Inside rim of turntable or idler wheel dirty, worn or dirty turntable thrust bearing.—The idler wheel and thrust bearing can be cleaned with alcohol. Lubricate only the thrust bearing and the shaft on the idler wheel. A nonslip solution can be applied to the turntable rim if it is polished due to wear. It may be necessary to replace the idler wheel if the rubber is hard or worn excessively.

Change cycle does not occur as stylus enters the lead-out groove.

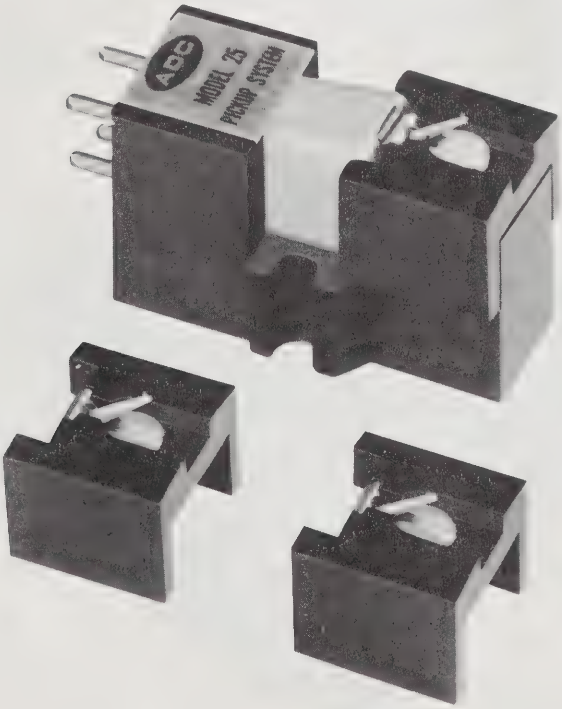
Velocity trip or main cam dirty or worn.—The velocity trip on the main cam clutch depends upon friction for proper operation. Make sure it is clean and NOT lubricated.

Turntable slows during change cycle.

Binding in the mechanism, slippage in the drive assembly.—Clean the turntable rim and idler wheel. Make sure all levers, cams, etc., are free. An accumulation of dirt can often jam the mechanism.

Unit does not cycle when start or "reject" button is pressed.

Start lever or main cam clutch trip bent, dirty or misadjusted; defective switch.—Check movement of start lever and make sure it trips the main cam clutch; adjust as necessary. Clean all levers, slides, etc., and lubricate with a good grade of grease. Check power switch to make sure it is closing.



This pickup unit employs interchangeable styli to allow the user to select the proper type for the record being played.
Courtesy Audio Dynamics Corp.

Hum.

> Faulty ground connection. Cartridge leads reversed. Defective cartridge. Pickup leads shorted. Ground loop (see manufacturer's instructions for proper ground connections). Broken ground strap from motor to chassis or from tone arm to chassis. Ground lead from chassis disconnected from amplifier. Cartridge ground wire(s) shorting to chassis ground.

The troubles and corrections presented are those most commonly encountered with record changers and automatic turntables. A conventional manual play turntable does not employ an automatic mechanism and is much easier to service. Many high-quality music systems employ this type of unit. Extra care in servicing these units is essential because a small amount of rumble or speed variation may be noticeable, whereas a typical home entertainment system may not show it.

PERFORMANCE TESTING AND ADJUSTMENTS

In addition to identifying the more obvious irregularities, the service technician should be well acquainted with performance testing of a turntable. An elaborate component stereo system is far more sensitive to defects and misadjustments than is a portable phonograph. Accordingly, it should receive special attention from the technician.

High-quality component turntables all use magnetic cartridges. Magnetic cartridges have greatly improved performance characteristics but have far less output than ceramic or crystal cartridges. To compensate for this low output, a high-gain preamplifier is used. The resultant sensitivity is now greater than that of a ceramic or crystal pickup and, as such, it is more responsive to vibrations and turntable deficiencies. In addition, stereo systems are more critical than monaural systems.

Many of the problems associated with high-quality turntables are the result of misadjustments, rather than mechanical problems. These adjustments will be discussed and should be checked before other problem sources are considered.

Next, the drive assembly should be inspected for dirt and grease accumulations and loose hardware.

Thirdly, the mechanical components of the problem area should be thoroughly inspected for wear.

There is a significantly greater array of measures of turntable performance than the average technician may realize. The importance of each cannot be overemphasized, as the technician's ability to cope with them is directly related to his customer's satisfaction.

The technician will need a rather unlikely piece of test equipment for performance testing—a stereo amplifier (and preamplifier) with speakers. It is important that this system be in good working order and completely free of hum. Several types of stereo test records and a **STROBE DISC** will also be required. A strobe disc is a record-sized disc with printed lines or dots used to determine turntable speed through stroboscopic means. When viewed under a fluorescent or neon light, the printed pattern on the disc will appear to be stationary when the turntable speed is correct.

The strobe disc technique is useful in determining overall speed accuracy of the turntable, but is not likely to help you spot small cyclical speed variations. These variations are known as **WOW and FLUTTER.** Wow is a low-frequency variation, causing an audible pitch fluctuation; while flutter is a higher frequency version, causing sound to be impure or gargly. If you can detect any wow or flutter, something is wrong. Small amounts of wow may

This automatic turntable features a mechanically controlled pivoting pickup head, giving minimum lateral tracking error to the cartridge.
Courtesy Garrard Div., British Industries Corp.

not be easily observed on a normal record, so a test record is recommended. Most test records include a series of tones, each having more wow than the previous tone. When you can begin to discern an increase in wow, the prerecorded wow has just exceeded the turntable wow.

If a customer complains of turntable rumble, cue the test record to a quiet passage (an unrecorded groove) of the test record, set the amplifier's bass control to maximum and gradually increase the volume control. Rumble will be clearly heard if this is the problem. Should no rumble be heard, the problem may be **ACOUSTIC FEEDBACK.**

Acoustic feedback occurs when vibrations from the speaker system are received by the pickup cartridge and produce a self-sustaining howling noise. This howl is often of a low pitch and easily confused with rumble. If you suspect acoustic feedback, advise the customer to lightly tap the turntable while it is on. This action often triggers the "ringing" of acoustic feedback. Advise the customer that acoustic feedback can usually be cured by moving the turntable farther away from the speakers, placing the turntable on a foam pad, or redirecting the speakers.

When a tone arm tends to skip toward the record's center, the problem is known as skating. This condition is caused by the force applied to the stylus by the outer groove of the record. Incorrect stylus pressure or a worn stylus can increase this problem, but it is likely that the main problem is a misaligned antiskating control. Normally, this control is preadjusted by the factory, but a change of cartridge may disturb the effectiveness of the setting. The antiskating control should only be aligned in accordance with the manufacturer's service information. In any situation, first check the condition of the stylus and the dynamic balancing of the tone arm.

The technician should also be aware of two other alignment problems and their effect on performance. **LATERAL TRACKING ANGLE ERROR** and **VERTICAL TRACKING ANGLE** cause distortion and excessive record wear.

Lateral tracking angle error is an indication of the amount that a pickup stylus deviates from perfect tangency to the record grooves as the tone arm moves across the record. On most turntables, the point of minimum lateral tracking angle error only occurs in two places. As illustrated by Figure 20, it is necessary to position the tone arm so that the stylus is sometimes forward of the center spindle. This positioning is known as **STYLUS OVERHANG.**

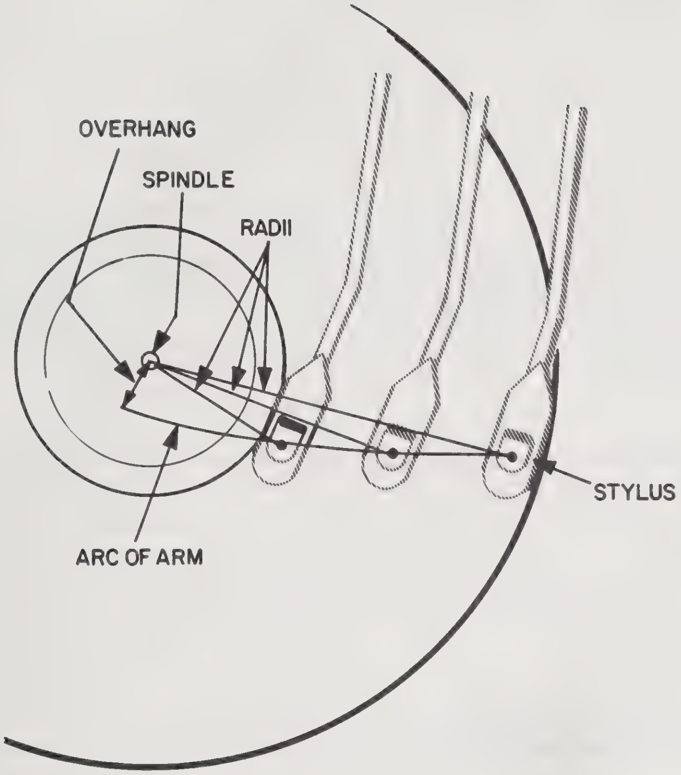


Figure 20

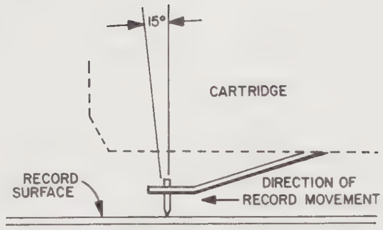


Figure 21

Vertical tracking angle is quite different. It is the vertical angle at which the stylus contacts the record as viewed from the side of the cartridge. Figure 21 shows the optimum vertical tracking angle of 15°. This angle is optimum because it matches that used by record manufacturers to cut the master record. The 15° angle can be attained by repositioning either the cartridge or the tone arm. On automatic turntables, a manual or automatic vertical tracking angle compensation may be featured. This device raises or lowers the tone arm pivot point to compensate for the height of the records stacked on the platter. Its operation should be checked against the manufacturer's service data.

PERFORMANCE TROUBLESHOOTING

Unit operates at incorrect speed.

> Motor pulley out of alignment. Idler wheel out of alignment. Wrong motor pulley (may be set for 50-Hz operation). Bent speed selector cam. Defective motor.

Wow and flutter.

See "speed variation" section of Troubleshooting Procedures.

Rumble.

Flat spots on the idler wheel or drive surfaces. Bent platter rim or spindle. Dirt and/or grease accumulation on drive surfaces. Unit mounted too rigidly. Worn platter spindle bearing. Motor mounting grommets damaged or missing. Motor mounting hardware loose. Poor design (applies to low cost portables).

Acoustic feedback.

Speakers too close to turntable. Unit mounted too rigidly. Pickup leads too tight.

Skating.

Improper stylus pressure. Arm not balanced. Faulty stylus. Antiskating control is out of adjustment.

Distortion.

Incorrect lateral or vertical tracking angle. Faulty stylus or cartridge. Improper stylus pressure.

Loss of frequency response.

Faulty stylus or cartridge.

The turntable or changer should be exactly level or improper operation may occur. Special circular levels are available for leveling turntables and record changers. Also, the shock mount springs must be adjusted to prevent the stylus from skipping from one record groove to another when a person walks across the room.

SUMMARY

Record changers and turntables are mechanical devices and subject to mechanical failure. Your best service tool is careful observation of the operation of the mechanism. In this way, you can determine what is not

The following Practice Exercise questions cover the subjects which you have just studied. They are:

A COMPLETE RECORD CHANGER

TROUBLESHOOTING PROCEDURES

PERFORMANCE TESTING AND ADJUSTMENTS

PERFORMANCE TROUBLESHOOTING

28. What is the result of too low a stylus pressure and of too high a stylus pressure?

29. Normally, the pickup arm set down has to be adjusted for each size record (7″, 10″ and 12″). True or False?

30. The idler wheel and thrust bearing can be safely cleaned with alcohol. True or False?

31. What is the result of slippage in the drive system?

32. Ceramic cartridges require high-gain preamplifiers because of their low output. True or False?

33. Explain the operation of a strobe disc.

34. If a customer complains that his turntable has high rumble, but none is heard in a test, what is the likely cause?

35. If skating occurs, what should be checked before the antiskating control?

36. Both lateral and vertical tracking angle error cause audible ________.

37. The optimum vertical tracking angle is __________.

38. A worn platter spindle bearing will probably cause ________________.

functioning and make the necessary repair. Most units can be operated at slow speed by rotating the turntable by hand.

Speed variation problems are the most common and are generally caused by worn drive pulleys. Sometimes the application of a nonslip compound will cure the troubles. However, replacement of the component is the best procedure.

Proper cleaning and lubrication of the automatic record change mechanism is very important. Over lubrication can cause an accumulation of dirt and result in improper operation.

High-quality stereo turntables are far more sensitive to irregularities than are low cost units. Many of these faults can be traced to the improper alignment of mechanical components. A stereo amplifier (and preamplifier) with speakers, a strobe disc and test records are required to evaluate the performance of a high-quality turntable.

IMPORTANT DEFINITIONS

AUTOMATIC TURNTABLE—A high-quality record changer that approaches or equals the performance characteristics of a professional turntable.

ACOUSTIC FEEDBACK—Vibrations from the speaker system that are transmitted back to the pickup cartridge, producing a self-sustaining, howling noise. Also sometimes called "howling."

DYNAMIC BALANCING—The process of balancing a tone arm in all planes. It is achieved by first adjusting stylus pressure to zero, moving the tone arm counter weight until the arm is balanced, and then readjusting the stylus pressure for the desired tracking force.

FLUTTER—A high-frequency wavering of recorded signals caused by rapid repetitive turntable speed variations.

LATERAL TRACKING ANGLE ERROR—An indication of the amount that the pickup stylus deviates from perfect tangency to the record grooves as the tone arm crosses the surface of a record.

RUMBLE—A low-frequency sound generated by vibrations in the motor or mechanism of a turntable (mostly in the vertical plane) that is picked up and reproduced by the cartridge.

SKATING—The tendency of a tone arm to slide toward the center of the record, caused by the force applied to the stylus by the outer groove of the record.

STROBE DISC—A record-sized disc with printed lines or dots used to determine turntable speed through stroboscopic means. The pattern appears stationary when the disc is viewed under fluorescent or neon light and when the turntable speed is correct.

STYLUS OVERHANG—The amount that the pickup stylus must be located forward of the turntable center spindle to achieve minimum tracking error.

VERTICAL TRACKING ANGLE—The vertical angle at which the stylus contacts the record as viewed from the side.

WOW—A low-frequency wavering of recorded signals caused by slow, repetitive turntable speed variations.

PRACTICE EXERCISE SOLUTIONS

1. Operate the unit at slow speed by rotating the turntable by hand.

2. Speed change is accomplished by moving the idler wheel up and down the motor pulley through a cam and rocker arm assembly.

3. The smallest diameter step would provide the lowest speed.

4. The speed is made variable by tapering the steps on the motor pulley as shown in Figure 4.

5. (b) decreases the speed.

6. (a) idler wheel.

7. Flat spots on the idler wheel usually cause a thumping sound and possibly a variation in speed.

8. Defective turntable thrust bearing, worn motor bearings, flat spots and irregularities in the drive system can cause rumble.

9. Over lubrication can cause an accumulation of dirt and result in improper operation.

10. Pop filter.

11. (b) synchronous motor.

12. To prevent hum and noise pickup by the cartridge.

13. True

14. A record changer contains a mechanism to automatically play a stack of records. A turntable is designed for single play manual operation.

15. False—Some parts should not be lubricated as they depend upon friction for proper operation.

16. In the normal or rest position, the turntable drive gear rotates in the open section of the main cam. To trip the clutch, a trip pin is pushed outward so it engages the teeth on the drive gear. This rotates the main cam enough to engage its teeth and start a cycle of operation.

17. An eccentric slot produces horizontal movement while a raised cam surface produces vertical movement as the cam rotates.

18. Normal movement of the pickup arm does not move the clutch lever far enough to engage the dog on the turntable drive gear. Once the lead-out

PRACTICE EXERCISE SOLUTIONS (Continued)

grooves are reached on the record, the pickup arm moves the clutch lever far enough to engage the dog on the turntable drive gear.

19. No—Proper operation depends upon friction between the friction plate and the clutch lever.

20. Rotation of the eccentric moves the bottom record off the shelf, allowing it to slide down the spindle to the turntable surface.

21. Either the spindle mechanism would not operate or, if it did, the record might not slide past the bent spot.

22. The 10″ record will not strike the edge of the 12″ lever, thus setting the mechanism for a 10″, 78 RPM record.

23. (c) stabilizing arm.

24. Movement of the start lever toward the main cam trips the main cam clutch.

25. False—The record size is selected manually.

26. The cam follower lever switches the main lever so that it follows either the inner or outer slot on the main cam.

27. (b) outside slot in the main cam.

28. Too low a stylus pressure will cause tracking problems and too high a stylus pressure will cause excessive stylus and record wear.

29. False—Usually one adjustment for the 7″ size will set the adjustment for the 10″ and 12″ sizes.

30. True

31. Slippage in the drive system can cause speed variations, a slowdown during the change cycle or even a stoppage during the change cycle.

32. False—A ceramic cartridge has a high output. A magnetic cartridge requires a high-gain preamplifier.

33. A strobe disc is placed on a platter and brought up to playing speed. The disc is then viewed under a fluorescent or neon light. If the playing speed is correct, the pattern on the disc will appear to stop.

34. Acoustic feedback.

PRACTICE EXERCISE SOLUTIONS (Continued)

35. Tone arm balance and stylus condition.

36. distortion

37. 15°

38. rumble

DE VRY INSTITUTE OF TECHNOLOGY
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ONE OF THE
BELL & HOWELL SCHOOLS

7540A
EXAMINATION CHECK SHEET

7540A

1. C - THE DRIVE SYSTEM SHOWN IN FIGURE 2 OPERATES AT 78 RPM WHEN THE IDLER WHEEL IS ON WHICH STEP OF THE PULLEY? -- BOTTOM.
On any other step, the idler wheel would make fewer rotations.

2. C - THE DRIVE SYSTEM SHOWN IN FIGURE 4 PROVIDES -- FOUR SPEEDS, EACH SLIGHTLY VARIABLE.
The steps on this motor pulley are tapered to allow a 6% to 10% speed variation.

3. C - FLAT SPOTS ON THE IDLER WHEEL USUALLY CAUSE -- RUMBLE.
A flat spot on the idler wheel disturbs the smooth transmission of power from motor to platter.

4. C - IF C_1 IN FIGURE 6 OPENS, -- NOISE WILL OCCUR IN THE AMPLIFIER OUTPUT WHEN THE TURNTABLE IS TURNED ON OR OFF.
C_1 is a part of the pop filter.

5. A - THE MECHANISM WHICH POSITIONS THE PICKUP ARM AND DROPS THE RECORDS IS GENERALLY DRIVEN BY THE -- MAIN CAM.
As shown in Figure 10A, the main cam controls both the vertical and horizontal pickup arm movement.

6. D - THE ACTUATING ARM IN FIGURE 11 TRIPS THE MAIN CAM CLUTCH WHEN THE -- PICKUP STYLUS ENTERS THE LEAD-OUT GROOVE ON THE RECORD.
The large movement of the pickup arm forces the clutch lever to engage the actuating arm.

7. A - A RECORD IS DROPPED TO THE TURNTABLE WHEN THE ECCENTRIC IN THE SPINDLE OF FIGURE 13 -- ROTATES TO THE POSITION IN FIGURE 13C.
This removes the force which holds the record.

8. A - IF THE CHANGE LEVER IN FIGURE 16A JAMS IN THE POSITION SHOWN, -- THE UNIT WILL NOT SHUT OFF AFTER THE LAST RECORD IS PLAYED.
No pressure would be applied to the power switch.

9. B - IN ORDER TO OBSERVE SMALL AMOUNTS OF WOW, -- A TEST RECORD IS USED.
Passages of a tone with increasing wow are played until the wow can be detected.

10. D - LATERAL TRACKING ANGLE ERROR CAN BE MINIMIZED BY -- STYLUS OVERHANG.
This increases overall tangency of the stylus to record groove.

QUESTIONS

IMPORTANT—These instructions **MUST** be accurately followed to avoid loss, or errors in grading.

Indicate your answer on this sheet by filling in the box for the most correct answer to each question, as illustrated in the example below.

When all questions have been answered, place the answer card in the proper position to line up the boxes on the card with the boxes on the sheet.

Next, copy the complete lesson code into the space provided on the card, and fill in the answer boxes to correspond with those previously filled in on this sheet.

Before mailing, be certain your correct student number, name and address appear on the card.

LESSON CODE
7540A

Example: North America is
A ☐
B ☐
C ■
D ☐
(A) an island. (B) a country.
(C) a continent. (D) a peninsula.

1. A ☐ B ☐ C ☒ D ☐
The drive system shown in Figure 2 operates at 78 RPM when the idler wheel is on which step of the pulley?
(A) Top. (B) Second from the top. (C) Bottom. (D) Third from the top.

2. A ☐ B ☐ C ☒ D ☐
The drive pulley shown in Figure 4 provides
(A) four fixed speeds only. (B) an infinitely variable speed. (C) four speeds, each slightly variable. (D) only 33¹/₃ RPM operation.

3. A ☐ B ☐ C ☒ D ☐
Flat spots on the idler wheel usually cause
(A) a higher than normal speed. (B) a lower than normal speed. (C) rumble. (D) the motor to overheat.

4. A ☐ B ☐ C ☒ D ☐
If C_1 in Figure 6 opens,
(A) wow will occur. (B) rumble will occur. (C) noise will occur in the amplifier output when the turntable is turned on or off. (D) there will be no noticeable effect.

5. A ☐ B ☐ C ☐ D ☐
The mechanism which positions the pickup arm and drops the records is generally driven by the
(A) main cam. (B) idler wheel. (C) speed change cam. (D) turntable rim.

6. A ☐ B ☐ C ☐ D ☒
The actuating arm in Figure 11 trips the main cam clutch when the
(A) pickup stylus enters the lead-in groove on the record. (B) pickup arm is lifted. (C) turntable stops. (D) pickup stylus enters the lead-out groove on the record.

7. A ☒ B ☐ C ☐ D ☐
A record is dropped to the turntable when the eccentric in the spindle of Figure 13
(A) rotates to the position in Figure 13C. (B) moves upward. (C) moves downward. (D) rotates to the position in Figure 13B.

8. A ☒ B ☐ C ☐ D ☐
If the change lever in Figure 16A jams in the position shown,
(A) the unit will not shut off after the last record is played. (B) the unit will not play the last record. (C) the record drop will not operate. (D) the main cam clutch will not trip.

9. A ☐ B ☒ C ☐ D ☐
In order to observe small amounts of wow,
(A) a strobe disc is used. (B) a test record is used. (C) the amplifier bass is increased. (D) the tone arm is balanced.

10. A ☐ B ☐ C ☐ D ☒
Lateral tracking angle error can be minimized by
(A) setting the vertical tracking angle at 15°. (B) lubricating the thrust bearing. (C) reducing flutter. (D) stylus overhang.

TAPE RECORDER REPAIR

7545

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Tape decks, like the one shown above, include recording amplifiers and playback preamplifiers. In addition, this deck provides automatic tape reverse as well as self threading.

Bell and Howell Photo

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Things don't turn up in this
world until somebody turns
them up.
—Garfield

TAPE RECORDER REPAIR

Several kinds of tape recorders are available for use as consumer, industrial and institutional products. Stereo tape recorders provide relaxing music in our homes and automobiles. Schools use tape recorders for language and speech training. Industrial uses include in-plant training, information storage, etc. The list goes on and on.

Maintenance and repair of tape recording equipment can become a major part of an electronic service technician's business. Most recorders are of good quality and when necessary, extensive repair is justified. However, there are some low-priced units on the market where it may be more profitable to replace the unit, rather than repair it.

Tape recorders, like record changers and turntables, are mechanical in nature, and subject to some of the same mechanical problems. Some of the electronic circuits employed in tape recorders are similar to those found in hi-fi/stereo amplifiers and radio-television receivers. The servicing procedures for tape recorders are therefore not very different from those used for receivers, amplifiers and record players.

MAGNETIC TAPE RECORDING

A basic component in a magnetic tape recording system is the magnetic tape. The tape consists of a plastic base, a coating of iron oxide particles, and the binder that bonds the oxide particles to the base. Most audio tapes are .5 mil to 1.5 mils thick (.0005″ to .0015″), and about 70% of this thickness is the base material.

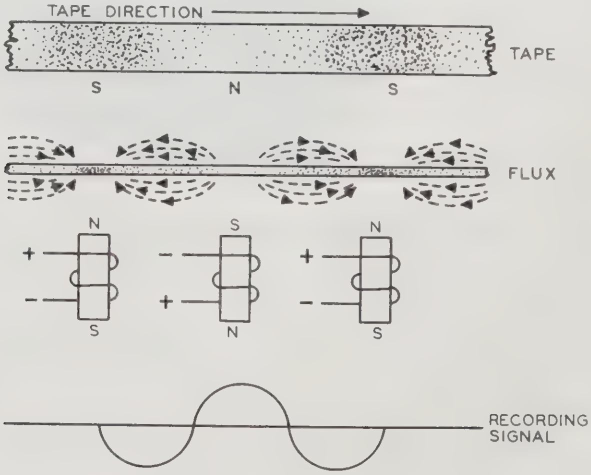
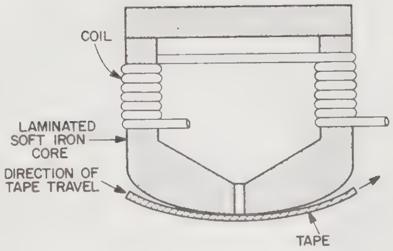


Figure 1

Information is placed on the tape by magnetizing the oxide coating with the recording signal. Figure 1 shows the magnetic tape during the basic recording process. During recording, the tape is moved past an electromagnetic assembly. The signals to be recorded are applied to the electromagnetic assembly, or RECORD HEAD, and a "magnetic impression" of the signal is left on the tape.



Recording a Signal

The record head construction and the manner in which a signal is recorded on the tape are shown in Figure 2. Signal current in the coils causes magnetic flux in the soft iron core. The circulating magnetic flux bridges the headgap by passing through the magnetic oxide layer of the tape that is traveling across the surface of the record head. The signal is recorded on the tape by the flux at the trailing edge of the headgap. The strength and polarity of the signal recorded on the tape are determined by the signal in the coils of the record head.

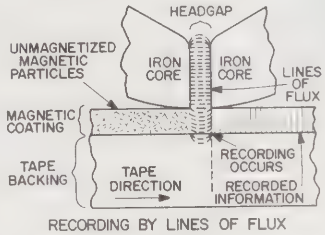


Figure 2

Bias

The magnetization, or tape transfer characteristic curve, of the iron oxide used for recording tape has a nonlinear region as shown in Figure 3. If an audio signal were recorded directly on the tape, it would be quite distorted. To eliminate this distortion, the recording signal must be "biased" so it does not operate in the nonlinear region. This is done by mixing a high-frequency ac current called **BIAS** with the recording signal current as shown in Figure 4. This bias signal is at least five times the frequency of the highest signal frequency to be recorded. Typical bias frequencies range from 80 to 200 kHz.

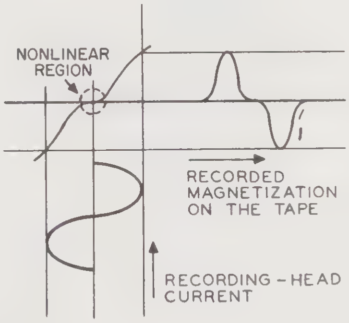
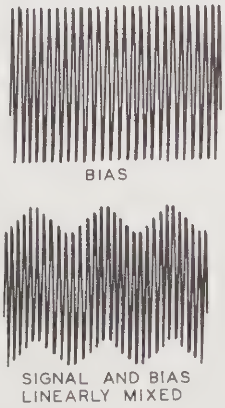


Figure 3

Figure 5 shows how the bias signal eliminates the distortion. The bias signal acts like a dc bias, except that it is effective on both portions of the magnetization curve. The bias signal is too high in frequency to be recorded on the tape, but the audio signal variations of the bias current are kept out of the nonlinear region of the tape's magnetization curve. The net result is an undistorted recorded signal.


BIAS

SIGNAL AND BIAS LINEARLY MIXED

Figure 4

The value of bias is very critical. Too much bias current or too little bias current will cause distortion. In critical applications, the value of bias current is different for each type of tape used. The technical manual for a given tape recorder will provide instructions for adjusting the bias level.

Some low-priced portable recorders employ a dc bias arrangement. This confines the recording to one or the other half of the magnetization curve.

Although the distortion is eliminated, the dynamic range is reduced. For dictation or voice recording, this is not a serious problem. Besides reducing the dynamic range, dc bias also tends to increase the tape noise level.

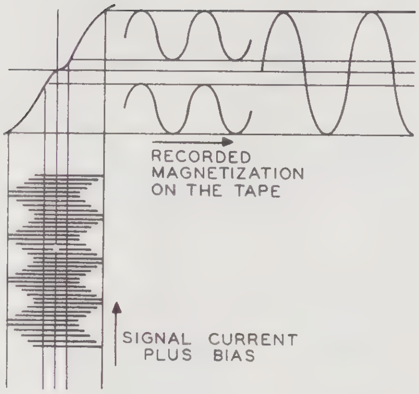
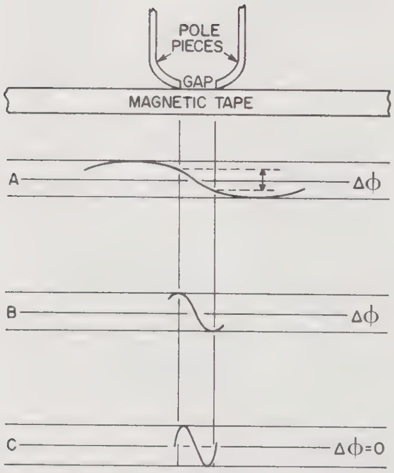


Figure 5

Playback

When playing back a prerecorded tape, the magnetic flux on the tape induces a signal in the coils of the PLAYBACK HEAD. The playback head output is connected to a high-gain preamplifier whose output goes to a power amplifier. In many recorders, the same head assembly is used for both record and playback. The mode selector switch setting determines what circuitry is connected to the head. Some recorders use separate playback heads and do not require this switching arrangement.



FREQUENCY RESPONSE OF A HEAD GAP

Figure 6

The playback frequency response limitations of the recorder are determined by the playback head gap width and the speed at which the tape passes the playback head. The wavelength of a recorded signal of a given frequency is longer on a tape moving at a high speed than it is on a tape that is moving at a slower speed. Therefore, at a high tape speed, a small portion of a low-frequency signal wavelength is across the gap width and, as shown in Figure 6A, the amplitude of the recorded flux, $\Delta\phi$, is small. If the tape were moving half as fast, twice as much of this signal wavelength would be across the gap width at the same frequency. The recorded flux, $\Delta\phi$, would then be higher in amplitude and would induce a stronger signal in the playback head. This shows that better low-frequency response is achieved at lower tape speeds.

As the recorded signal increases in frequency, more of the signal is across the headgap, and the recording flux, $\Delta\phi$, increases. The amplitude of $\Delta\phi$ is maximum when one-half cycle of the recorded signal wavelength is across the headgap, as shown in Figure 6B. At twice this frequency, when one entire wavelength is across the headgap, the flux at each end of the gap width is identical, as shown in Figure 6C. At this point $\Delta\phi$ is zero, and no signal is induced in the playback head. If the tape speed were doubled, the conditions for this same frequency would then be as shown in Figure 6B. This shows that better high-frequency response is achieved with higher tape speeds and smaller headgaps.

To provide good high-frequency response, most high-quality tape recorders have playback head gap widths of less than .25 mil (.00025″). Most consumer reel-to-reel tape recorders have tape speeds of $7^{1}/_{2}$, $3^{3}/_{4}$ and $1^{7}/_{8}$ inches per second (ips). Cartridge machines run at $3^{3}/_{4}$ ips and cassette units run at $1^{7}/_{8}$ ips. Higher tape speeds make good high-frequency response more easily obtainable.

Equalization

Certain factors also cause nonlinearities in frequency response of the signal that is recorded on the tape. To compensate for these nonlinearities and to improve the signal-to-noise ratio on the tape, the signal is applied to an equalization network before recording. Typical curves for recording equalization are shown in Figure 7. The exact amount of equalization used depends on the characteristics of the record head and the type of tape that is used.

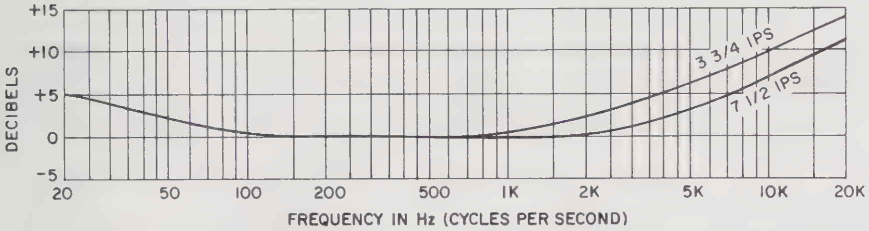


Figure 7

As explained previously, the frequency response of a playback head is maximum when the headgap size is one-half the recorded wavelength of the signal. Above this frequency, playback response falls off very rapidly. Below this frequency, playback response falls off at a rate of 6 dB per octave.

To compensate for these frequency irregularities, and also for the equalization of the recorded signal, standard playback frequency equalization curves have been selected for use, as shown in Figure 8.

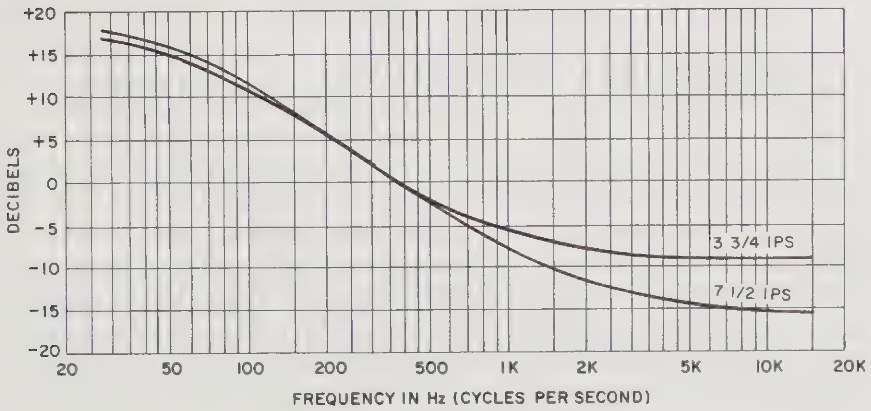


Figure 8

The output signal taken from the playback head goes to a preamplifier whose output is applied to an equalizer network whose response is shown by the curves of Figure 8. The resultant output of the equalizer network is a signal with relatively flat frequency response.

Erasing

One of the advantages of magnetic tape is that the signals can be "erased" and the tape used over again. Erasing is accomplished by subjecting the tape to a strong magnetic field that removes the magnetic pattern forming the signal. One of the most common methods is to use the same high-frequency signal that is used for bias. This signal is fed to a separate head called the ERASE HEAD. The high-frequency signal from the erase head is not reproducible and it effectively removes the signal from the tape.

Some of the lower priced units erase the tape by placing it in the field of a permanent magnet. Although this erases the tape, it tends to increase the noise level. The erase head is activated whenever a signal is to be recorded. The erase head is located ahead of the record head in the path of tape travel so that the tape is erased before recording. Most tape recorders have an interlocking switch arrangement which requires two buttons to be pressed before recording can occur. This helps to prevent accidental tape erasure.

Bulk tape erasers are also popular. These units are actually large electromagnets that operate off the 60-Hz line. The magnetic field starts at full strength and then gradually decreases to zero to erase the tape. On some hand-held units, the bulk eraser is slowly moved away from the tape reel before the eraser is turned off. If the unit were abruptly turned off while the tape was in the influence of the magnetic field, it would magnetize the tape to the level and polarity of the line current at the instant that the eraser was turned off.

RECORDING AND PLAYBACK AMPLIFIERS

Most tape recorders consist of a tape transport and electronics containing recording and playback amplifiers. Separate amplifiers can be used for recording and playback, or parts of the same amplifiers may be used for both. Some tape units are made for playback only, such as automotive 8-track stereo players, and these only contain playback amplifiers. Some tape units contain no amplifier circuits at all. These units are referred to as tape transports. For playback, they can be connected to regular hi-fi/stereo amplifiers that have input circuitry for tape heads. Special amplifiers are needed for recording.

Figure 9 shows a typical combination recording and playback amplifier. Only the preamplifier and power amplifier for one channel are shown. The other channel is identical.

The circuit of Figure 9 employs a conventional full-wave rectifier in the power supply to provide the operating voltage for the various circuits. Diodes CR_{501} and CR_{502}, together with power transformer T_{502}, form a full-wave rectifier circuit. Voltage divider resistors R_{565}, R_{566} and R_{567}, together with capacitors C_{547A}, C_{547B}, C_{547C} and C_{546}, form the voltage dividers and filter circuit. Switch S_{502} controls the voltage at point A, 29.5 volts. This voltage is applied to the bias oscillator when S_{502} is closed during record. During playback, the bias oscillator is inoperative.

The tape transport drive motor is connected in the primary side of power transformer T_{502}, and is energized wherever the unit is turned on. A system of belts, pulleys and linkages drive the mechanism.

The amplifiers and other circuitry for the tape recorder are mounted on separate printed circuit boards, as indicated by the dashed-line boxes in Figure 9. The bias/erase oscillator circuit consists of Q_{308} and Q_{309}, along with L_{302} and the associated components. This particular circuit arrangement is a push-pull oscillator. The push-pull configuration eliminates even harmonic distortion. The oscillator waveshape is important. A distorted bias signal can result in distortion of the recorded signal. This particular circuit uses a bias frequency of 80 kHz, which is typical for many home-entertainment type recorders.

S_{101E} and S_{201E} are part of the Record/Playback switch. In the playback position, the output from the bias/erase oscillator is grounded and not applied to the erase heads. During recording, power is applied to the bias/erase oscillator, and the erase heads are connected to the oscillator output. The output from the oscillator is also applied to the recording heads through an RC network. The connection to the record heads is from point X above the left-hand winding of oscillator output transformer L_{302}. This is connected to the left channel record head through point X in the lower left-hand portion of the schematic. Potentiometer R_{224} is used to adjust the amount of bias current for the left channel record head.

The power amplifier consists of the driver stage, Q_{205}, and the Q_{206}, Q_{207} push-pull output stage. The output of the amplifier is a conventional Class B transformerless output circuit. The driver transformer T_{201} provides the required 180° out-of-phase signals to the output stage bases. R_{236} sets the bias for the driver stage. Negative feedback is provided by R_{247} to improve frequency response and reduce distortion.

The signal applied to the power amplifier is controlled by volume control R_{286B}. This control is part of a dual control with the other half of R_{186A} in the other channel. Tone control R_{285B} is simply a treble loss circuit. Moving the movable contact of R_{285B} towards the ground end decreases the impedance for high frequencies from the base of Q_{203} to ground. This reduces the high-frequency response, thus yielding an "apparent" bass boost.

On the preamplifier board, most of the circuitry is used for both recording and playback by appropriate switching. Let's examine the unit in the playback mode first. Multiple pole switch S_{201} sets up the preamplifier circuit for playback or recording. In the position shown, S_{201} is in the playback mode.

In the playback mode, S_{201D} grounds one side of the record/playback head and S_{201A} connects the other side through R_{201} and C_{202} to the base of Q_{201}. S_{201B} and S_{201C} short the microphone (mic) and source inputs to ground. The output signal from the collector of common emitter amplifier Q_{201} is coupled through C_{204} to the level control, R_{288}. From R_{288}, the signal is applied through R_{208} and C_{205} to the base of Q_{202}. From the collector of common emitter amplifier Q_{202}, the signal is applied through C_{206} to the base of Q_{203}. There is a feedback network from the Q_{203} collector to the Q_{202} emitter. The settings of record/playback switch section S_{201F} and speed equalization switch S_{406} determine what components are in the feedback network. The setting of S_{201F} determines whether record or playback equalization is used, and the setting of S_{406} determines the frequency response of the equalization.

From the collector of Q_{203}, the signal is applied through C_{211} to volume control R_{286B} and the power amplifier. The signal is also applied through R_{270} to external amplifier jack J_{203} for use with a hi-fi music system. A VU meter is also connected to the output of Q_{203}. Although the meter functions on playback, its primary purpose is as an aid in setting the recording level. Potentiometer R_{217} is used to calibrate the VU meter.

The output signal from Q_{203} is also applied to the base of recording amplifier Q_{204}. However, during playback, the Q_{204} output is shorted by record/playback switch section S_{201D}.

For recording, S_{201} is placed in the record position. In addition, S_{502} applies power to the bias/erase oscillator. S_{201E} (S_{101E} in the other channel) applies the high-frequency erase signal to the erase head. S_{201A} connects the mic input to the base of Q_{201}, and S_{201C} connects the high level source input (such as a tuner output) to the level control.

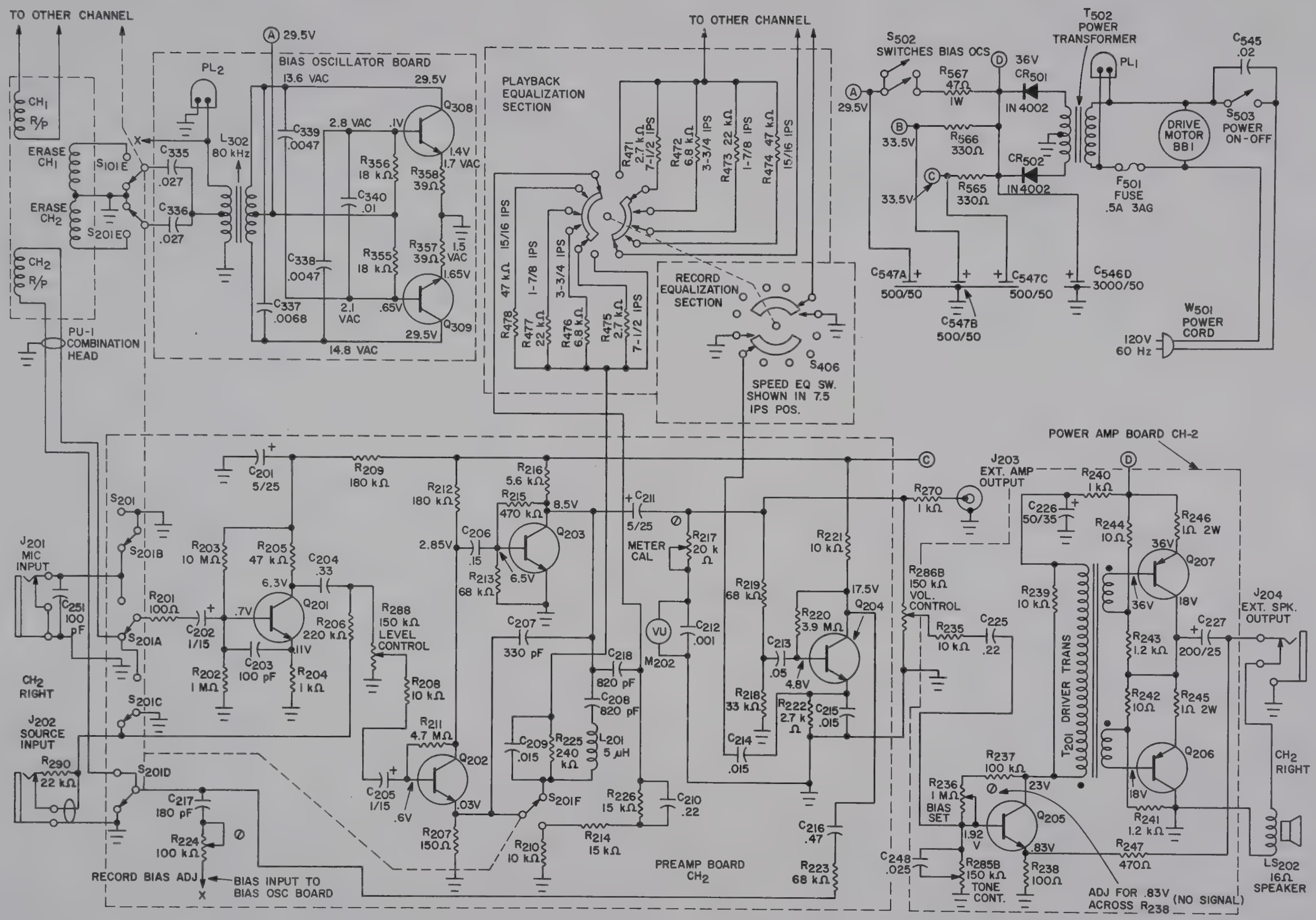

TO OTHER CHANNEL
Ⓐ 29.5V
BIAS OSCILLATOR BOARD
13.6 VAC
29.5V
PL2
CH1 R/P
ERASE CH1
S101E
ERASE CH2
S201E
CH2 R/P
C335 .027
C336 .027
L302 80 kHz
C339 .0047
2.8 VAC
.1V
Q308
1.4V
1.7 VAC
R356 18 kΩ
R358 39Ω
C340 .01
C338 .0047
R355 18 kΩ
R357 39Ω
1.5 VAC
1.65V
C337 .0068
2.1 VAC
.65V
29.5V
Q309
14.8 VAC
PU-1 COMBINATION HEAD
PLAYBACK EQUALIZATION SECTION
TO OTHER CHANNEL
R471 2.7 kΩ 7-1/2 IPS
R472 6.8 kΩ 3-3/4 IPS
R473 22 kΩ 1-7/8 IPS
R474 47 kΩ 15/16 IPS
15/16 IPS
1-7/8 IPS
3-3/4 IPS
R478 47 kΩ
R477 22 kΩ
R476 6.8 kΩ
R475 2.7 kΩ
7-1/2 IPS
RECORD EQUALIZATION SECTION
S406
SPEED EQ SW. SHOWN IN 7.5 IPS POS.
S502 SWITCHES BIAS OCS
T502 POWER TRANSFORMER
PL1
C545 .02
Ⓐ 29.5V
R567 47Ω 1W
Ⓓ 36V
CR501 IN4002
Ⓑ 33.5V
R566 330Ω
Ⓒ 33.5V
R565 330Ω
CR502 IN4002
DRIVE MOTOR BB1
S503 POWER ON-OFF
F501 FUSE .5A 3AG
C547A 500/50
C547B 500/50
C547C 500/50
C546D 3000/50
W501 POWER CORD
120V 60 Hz
POWER AMP BOARD CH-2
C201 5/25
R209 180 kΩ
R212 180 kΩ
R216 5.6 kΩ
R215 470 kΩ
8.5V
Q203
C211 5/25
Ⓒ
R270 1 kΩ
J203 EXT. AMP OUTPUT
Ⓓ
R240 1 kΩ
C226 50/35
R244 10Ω
R246 1Ω 2W
36V
Q207
18V
S201
S201B
J201 MIC INPUT
C251 100 pF
R203 10 MΩ
R205 47 kΩ
C204 .33
6.3V
R201 100Ω
C202 1/15
.7V
Q201
R206 220 kΩ
C203 100 pF
11V
R202 1 MΩ
R204 1 kΩ
S201A
R288 150 kΩ LEVEL CONTROL
2.85V
C206 .15
R213 68 kΩ
6.5V
METER CAL
R217 20 kΩ
R221 10 kΩ
R286B 150 kΩ VOL. CONTROL
R239 10 kΩ
36V
J204 EXT. SPK. OUTPUT
C207 330 pF
C218 820 pF
VU
M202
C212 .001
R219 68 kΩ
17.5V
R220 3.9 MΩ
Q204
C213 .05
4.8V
R235 10 kΩ
C225 .22
R243 1.2 kΩ
C227 200/25
CH2 RIGHT
J202 SOURCE INPUT
S201C
R208 10 kΩ
C208 820 pF
R218 33 kΩ
R222 2.7 kΩ
C215 .015
DRIVER TRANS
T201
R242 10Ω
R245 1Ω 2W
R290 22 kΩ
S201D
R211 4.7 MΩ
C209 .015
R225 240 kΩ
L201 5 μH
C214 .015
Q202
Q206
CH2 RIGHT
C217 180 pF
C205 1/15
.6V
.03V
S201F
R226 15 kΩ
C210 .22
R237 100 kΩ
R236 1 MΩ BIAS SET
23V
Q205
18V
R224 100 kΩ
R207 150Ω
R210 10 kΩ
R214 15 kΩ
C216 .47
1.92 V
.83V
R241 1.2 kΩ
C248 .025
R247 470Ω
LS202 16Ω SPEAKER
RECORD BIAS ADJ
BIAS INPUT TO BIAS OSC BOARD
PREAMP BOARD CH2
R223 68 kΩ
R285B 150 kΩ TONE CONT.
R238 100Ω
ADJ FOR .83V ACROSS R238 (NO SIGNAL)

Figure 9

The record signal is amplified by Q_{202} and Q_{203}, and then applied to the recording amplifier, Q_{204}. The output from Q_{204} is applied to the record/playback head through C_{216}, R_{223} and S_{201D}. S_{201C} grounds the other side of the head during recording. The high-frequency bias signal is also applied to the head through R_{224} and C_{217}. R_{224} is adjustable, so that the level of bias can be set for minimum distortion.

The signal applied to Q_{204} also appears at jack J_{203} and also the power amplifier input. This permits monitoring of the recording signal. Level control R_{288} is used to set the recording level. Normally, the level is set so that the average recording signal level indicates about −10 VU on the VU meter, with signal peaks just reaching 0 VU. If the recording level is too high, distortion and "print through" can occur. **PRINT THROUGH** is a transfer of the magnetic field from one layer of the wound tape to another. Volume control R_{286B} sets the level of the monitor signal.

As mentioned earlier, the circuit of Figure 9 employs common circuitry for both playback and recording. Some machines employ separate amplifiers. This permits special effects, such as sound-on-sound and echo, when separate record and playback heads are used.

Tape decks for use in hi-fi/stereo systems may contain a playback preamplifier and a recording amplifier. No power amplifier is included, as the one in the hi-fi/stereo system is used.

PERFORMANCE

Modern reel-to-reel tape recorders are capable of extremely high-quality performance. Some of the more expensive consumer tape recorders can provide recordings that are as good as any that may be obtained with studio-type equipment. These top-quality recorders use low-noise and high-output low-noise tapes for recordings with improved frequency response and higher signal-to-noise ratios.

The best reel-to-reel recorders can provide recordings made at $3^{3}/_{4}$ ips that are almost indistinguishable from program sources such as FM broadcasts or phonograph records. Such recordings may have a frequency response that is flat to beyond 15 kHz, and a signal-to-noise ratio of about 60 dB. At a speed of $7^{1}/_{2}$ ips, the frequency response may extend beyond 20 kHz, and the signal-to-noise ratio will be 6 dB better than at $3^{3}/_{4}$ ips. Many recorders provide switch-selected choices of record and playback equalization to match the types of tape that are used.

This 8-track cartridge player is designed for use in home music systems. The indicator lamps above the cartridge slot indicate the tracks being played.
Courtesy Concord Electronics Corp.

Many recorders contain filters that are designed to eliminate any 19, 38 or 67 kHz pilot or subcarrier signals that might accompany a signal from an FM tuner program source. Some recorders provide electronic logic control of modes of operation to prevent accidental recording and to eliminate the possibility of tape breakage.

TAPE TRACK ARRANGEMENTS

The magnetic tape used in most home recording application is $^1/_4''$ wide. For stereo recordings, at least two tracks must be recorded, one for the left channel information and one for the right channel information. By recording four tracks, two separate stereo programs can be recorded. Present practice is to put as many as eight tracks on $^1/_4''$ tape. This permits recording four separate stereo programs.

Figure 10 shows some typical recording track arrangements. Some single channel, or monaural recorders, employ the entire tape width for one signal, as shown in Figure 10A. This is called **FULL-TRACK** recording. The full-track arrangement provides an excellent signal-to-noise ratio, and it is sometimes used in broadcast applications.

A more common monaural recording arrangement is the **HALF-TRACK** arrangement shown in Figure 10B. The recording head gap assembly is only $^1/_2$ the width of the tape. The tape can be run through the recorder once to record on track 1. By reversing the supply and feed reels, the tape is flipped over, and a signal can be recorded on track 2. This doubles the amount of signal that can be recorded on the tape, compared to full-track recording.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

MAGNETIC TAPE RECORDING

RECORDING A SIGNAL

BIAS

PLAYBACK

EQUALIZATION

ERASING

RECORDING AND PLAYBACK AMPLIFIERS

PERFORMANCE

1. The basic coating material used on magnetic tape is ________________________.
2. The electromagnetic assembly used to record and reproduce signals on magnetic tape is called the __________.
3. List two factors which determine the frequency response of a magnetic tape system.
4. Of the choices given, which tape speed provides the widest frequency response? (a) $1^7/_8$ ips. (b) $3^3/_4$ ips. (c) $7^1/_2$ ips. (d) 15 ips.
5. What is bias in a magnetic tape recording system?
6. If the maximum signal frequency to be recorded is 15 kHz, what should the minimum bias frequency be?
7. The bias signal used in magnetic tape recording can only be a high-frequency ac signal. True or False?
8. Tape erasure is accomplished by feeding the high-frequency bias signal to an erase head. True or False?
9. What two functions are served by the bias oscillator?
10. In Figure 9, moving the slider on the tone control R_{285B} towards the base of Q_{205} (a) increases the high-frequency response, (b) increases the low-frequency response, (c) decreases the high-frequency response.

11. What is the function of S_{406} in Figure 9?

12. What stage in the preamplifier section of Figure 9 is not used during playback?

13. For normal recording the signal level should never exceed ________ VU on peaks.

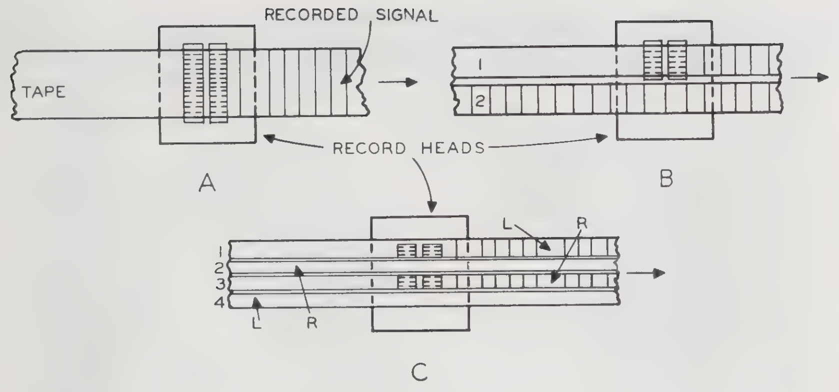


Figure 10

The half-track arrangement was also used in the early days of stereo recording. The left signal was recorded on one track and the right signal on the other. This was sometimes done with two staggered heads, although the more common arrangement was a single head with two gap assemblies.

The **FOUR-TRACK** recording arrangement shown in Figure 10C is almost universally employed for stereo recording. The record head contains two separate gap assemblies. The stereo signals are recorded on tracks 1 and 3, and when the tape is turned over, tracks 2 and 4 are recorded. The four-track arrangement allows twice as much material to be recorded on a given reel of tape, compared to the two-track arrangement.

The **EIGHT-TRACK** arrangement shown in Figure 11 is popular in automotive tape cartridge stereo systems. In these units, a separate selection is generally placed on each set of tracks—1 and 5, 2 and 6, 3 and 7, and 4 and 8. Switching from one selection to another is accomplished by mechanically moving the tape head up and down. Most units automatically move the head to the next set of tracks after all the selections on a pair of tracks have been played.

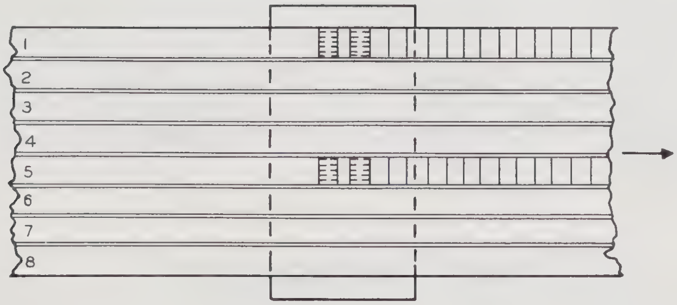


Figure 11

This tape deck employs three motors on the transport, one for the capstan and two reel turntable motors.
Courtesy TEAC Corporation of America

The track arrangements shown in Figures 10 and 11 are all employed on $^1/_4''$ wide tape. Thus, as the number of tracks increases, the width of each track decreases. As a result, mechanical alignment becomes more critical and the quality of the tape becomes more important. All tape contains coating imperfections. On playback, these imperfections can cause a momentary loss of signal, called a **DROPOUT.** Eight-track systems are more sensitive to dropouts than systems using less tracks since the imperfection is more apt to cover the full width of a narrow track.

TAPE TRANSPORTS

A tape recorder can be divided into two basic sections, the **TAPE TRANSPORT** and the electronic circuits. The tape transport includes the mechanical devices which move the tape past the erase, record and playback heads. The electronic circuits include the recording amplifier, the playback amplifier, the bias oscillator and the power supplies.

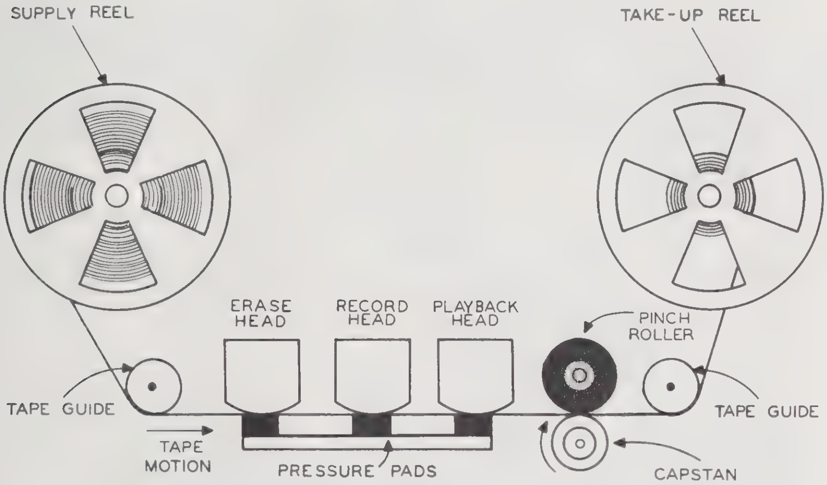


Figure 12

Figure 12 shows a typical tape transport. The capstan is rotated by the drive motor at a constant speed. A rubber-rimmed pinch roller presses the tape against the capstan to move the tape in the direction shown. The take-up and supply reels are driven through a belt and slip clutch arrangement. This is necessary because their speeds will vary with the amount of tape on the reels. The capstan and pinch roller provide a constant tape speed. A series of pressure pads press the tape against the three heads. Some of the more elaborate recorders employ three separate motors, one to drive the capstan, and a motor for each of the two reels.

The capstan drive arrangement is the most popular since it provides constant tape speed. Speed can be changed by changing the size of the capstan, or effecting changes in a belt arrangement that drives the capstan. Some inexpensive portable recorders do not employ a capstan drive, and their drive motors operate the tape reels directly. The speed is not constant from start to finish on a reel, and the recorded reel of tape can only be played properly on that unit.

Besides moving the tape past the heads for recording and playback, most tape transports provide for different forward speeds and also rewind and fast forward speeds. These functions are generally accomplished through a series of belts, pulleys and levers.

Figure 13 shows a typical tape transport drive system that uses one motor. The various belts and pulleys provide the following functions: STOP, PLAY/RECORD, FAST FORWARD, and REWIND. A system of pushbuttons or knobs is used to move the pulleys to provide the various functions.

The motor pulley is driven by the motor in the direction shown. The capstan which drives the tape is connected to a large flywheel which, in turn, is driven by the motor pulley through a belt. The flywheel helps to provide a more constant speed by damping out minor speed variations caused by line voltage fluctuations, etc.

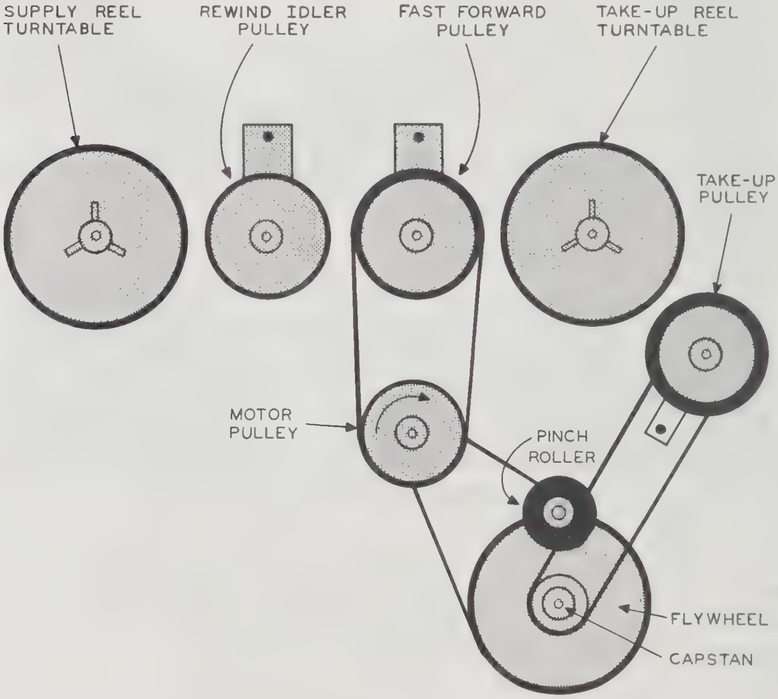


Figure 13

The mechanism position in Figure 13 is in the STOP position. Although not shown, a set of brake pads would be pressed against the rims of the reel turntables to hold them stationary in the STOP position.

Figure 14 shows the mechanism in the PLAY/RECORD position. The rubber rim on the take-up pulley is pressed against the rim of the take-up reel turntable, driving it in the direction shown. The pinch roller presses the tape against the capstan to move the tape past the heads at a constant speed. With the tape speed constant, the take-up reel speed must vary with the amount of tape that is wound on it. This speed variation is provided by the friction

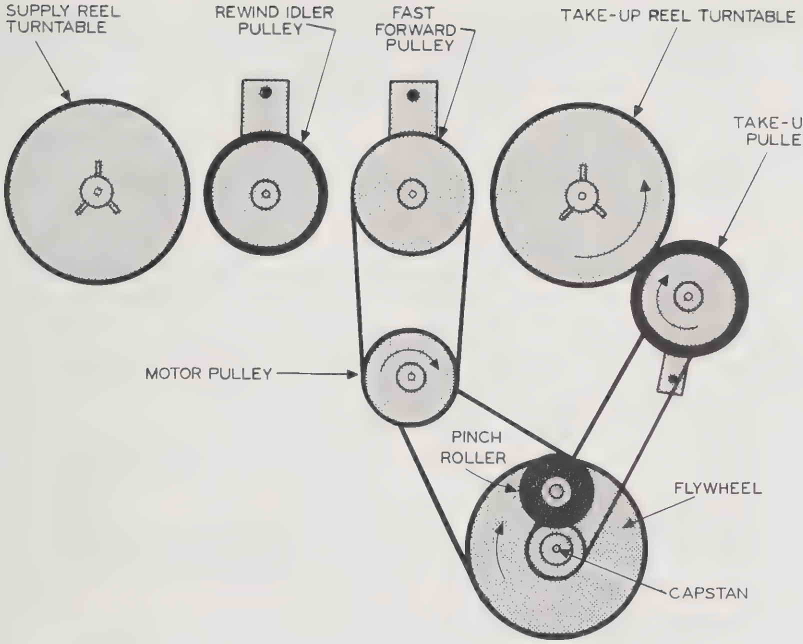


Figure 14

coupling between the take-up reel turntable and the take-up pulley. Although not shown, a brake pad would be lightly pressed against the supply reel turntable to keep the tape tight and prevent freewheeling motion of the supply reel.

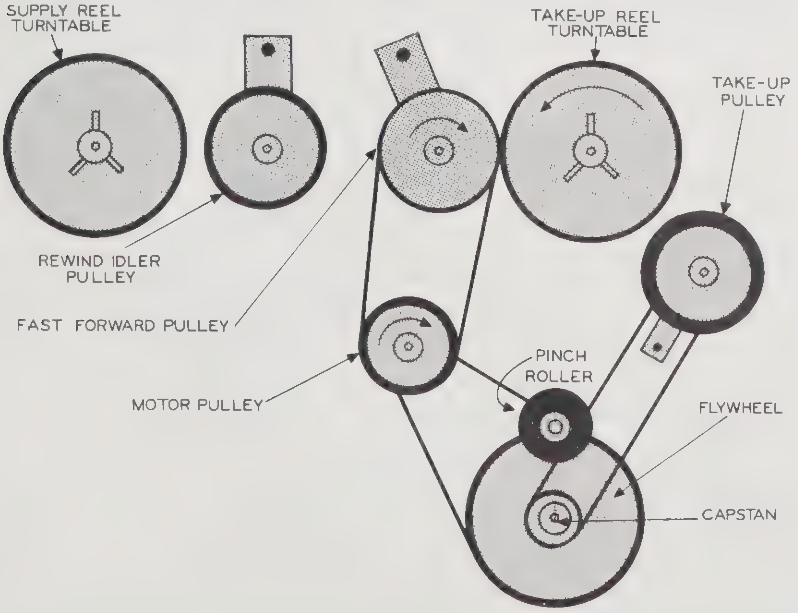


Figure 15

Most tape mechanisms provide a FAST FORWARD function to move the tape rapidly to some point on the reel. Figure 15 shows the mechanism in the FAST FORWARD position. The fast forward pulley is pressed against the take-up reel turntable rim. This provides a much faster reel speed than when the take-up reel is driven by the take-up pulley. Note that the pinch roller does not press the tape against the capstan during fast forward.

To prevent excessive head wear, mechanical linkages lift the tape away from the heads during fast forward. A drag brake pad also presses lightly against the supply reel turntable to prevent freewheeling motion which could cause tape spillage.

The REWIND function is provided by moving the fast forward pulley to the left, as shown in Figure 16. This presses the rewind idler pulley against the supply reel, driving it in the direction shown. A drag brake is lightly pressed against the take-up reel turntable to prevent freewheeling motion and tape spillage. As in fast forward, the pinch roller does not press the tape against the capstan, and the tape is lifted away from the heads.

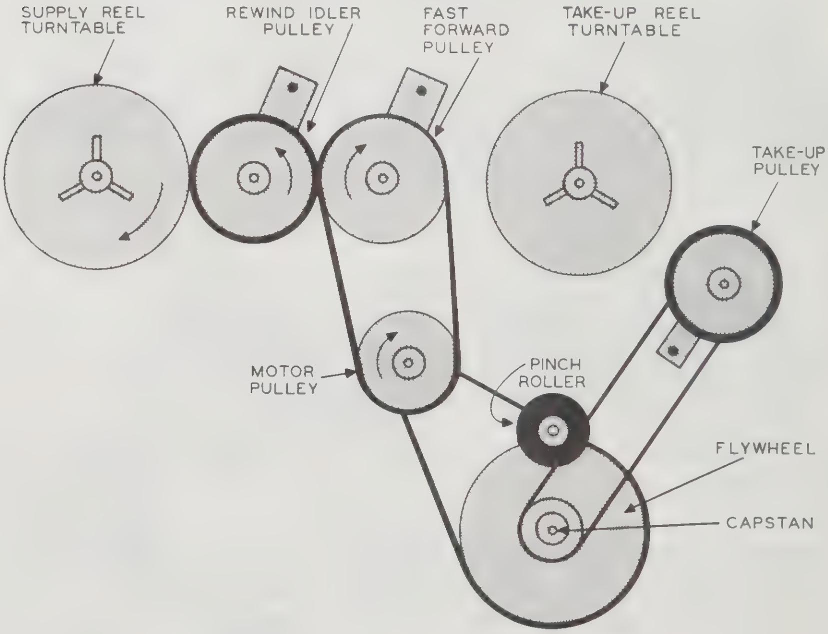


Figure 16

Speed change in a belt drive system is usually accomplished with a stepped motor pulley. Figure 17 shows a typical speed change arrangement. For the $7^1/_2$ ips speed, the drive belt rides in the upper larger diameter groove of the motor pulley. To change speed, the speed shift fork moves downward, causing the drive belt to slip into the smaller groove for $3^{3}/_{4}$ ips. Returning the speed selector lever to $7^{1}/_{2}$ ips moves the speed shift fork upward which returns the belt to the large diameter groove.

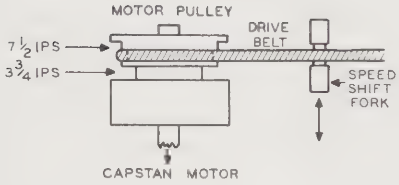


Figure 17

Another method of changing speed is to employ a drive motor with two separate windings. Energizing one winding provides a speed of $7^{1}/_{2}$ ips, and energizing the other winding provides a speed of $3^{3}/_{4}$ ips.

Some tape recorders use two motors: one to drive the capstan, and the other to drive the supply and take-up reels. This eliminates load changes on the capstan motor, and therefore provides smoother forward tape motion during record or play modes.

REEL MOTORS AND BRAKE SYSTEMS

Many tape recorders employ three motor tape transports instead of belt and pulley arrangements. One motor drives the capstan, and each reel is driven by a separate motor. The capstan motor operates at a constant speed, and the reel motor speeds are varied to suit the modes of operation. Figure 18 shows a simplified reel motor control system. The take-up and rewind motors are of the induction type, requiring phase splitting capacitors C_1 and C_2 for proper operation. S_{1A} and S_{1B}, along with R_1 through R_4, control the voltages applied to the motors to control their speeds.

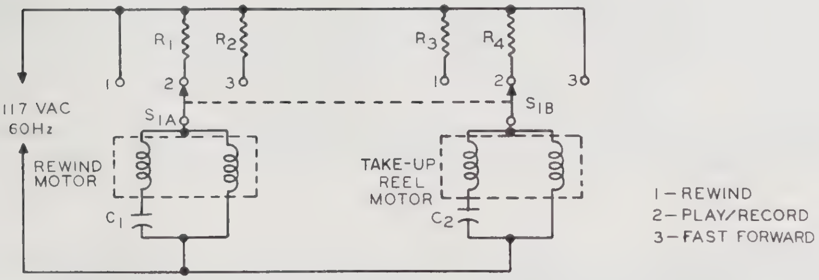


Figure 18

Switch S_1 is shown in position 2, the play/record mode. In this mode, the take-up reel motor receives about one-half normal voltage through R_4 to wind up the tape with sufficient tension. The rewind motor receives about one-fourth normal voltage through R_1 to apply a slight holdback tension to the tape.

When switch S_1 is in the rewind position (switch position 1) the rewind motor receives full voltage through S_{1A} and it runs at high speed. R_3 supplies the take-up reel motor with a small voltage to put a slight tension on the tape. The process is similar in the fast forward mode (switch position 3). Under these conditions, the take-up reel motor receives full voltage, and the rewind motor receives a small voltage through R_2 to provide a slight tape tension. The speed determining resistors R_1 through R_4 are generally made adjustable so that speed and holdback tensions can be properly adjusted.

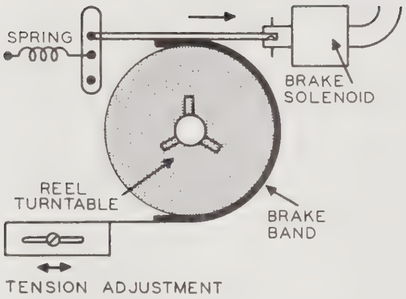


Figure 19

To prevent tape breakage and spillage, the reel motors must be stopped quickly and evenly. This is generally done with a brake system like that shown in Figure 19. When the brake solenoid is de-energized, the spring pulls the brake band against the reel turntable, stopping the turntable. Energizing the brake solenoid pulls the brake band away from the reel turntable, allowing it to rotate. The brake solenoid would be energized whenever the tape is in motion and de-energized when the tape is to be stopped. A separate brake solenoid assembly is generally included for each reel turntable assembly.

Many tape recorders employ automatic shut-off and reversing features when the end of the tape is reached. Automatic shut-off is usually accomplished with a microswitch that de-energizes the drive motors. A linkage attached to the microswitch is placed in the tape path. When tape is present, the linkage is held in a position that keeps the microswitch contacts closed. When the end of the tape passes the head assembly, the linkage is free to move. The linkage then pivots slightly, and the microswitch contacts open.

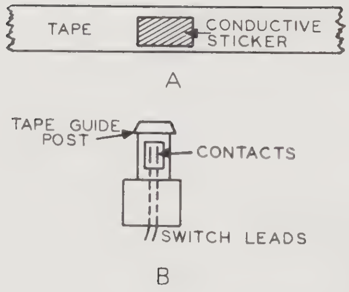


Figure 20

Automatic shut-off or automatic reverse is sometimes accomplished through use of a conductive sticker, placed near the end of the tape, as shown in Figure 20A. This conductive sticker is sensed by a set of contacts built into a tape guide post shown in Figure 20B. When the conductive strip passes over the contacts, it completes the circuit. The switch contacts generally operate a relay which controls the reel and capstan motors.

Automatic reverse is often accomplished by use of a subsonic (20 Hz) tone recorded on the tape. This tone is amplified by a special circuit that activates a relay whose contacts are used to initiate the process of playing the tape in the reverse direction. In some machines, extra heads are used, and no mechanical shifting of heads or tape path is required.

CASSETTE AND CARTRIDGE TRANSPORTS

Tape cassette and cartridge units have become very popular. Both types employ cases which hold the tape and are merely inserted into the tape players. Manual threading of the tape is eliminated in both of these systems.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

TAPE TRACK ARRANGEMENTS

TAPE TRANSPORTS

REEL MOTORS AND BRAKE SYSTEMS

14. For monaural recording, what is the advantage of half-track recording over full-track recording?

15. How many separate stereo signals can be recorded on an 8-track arrangement?

16. To provide a flat response, the playback amplifier must ____________ (boost or attenuate) the low frequencies and ____________ (boost or attenuate) the high frequencies.

17. What is the advantage of a capstan tape drive?

18. How does the mechanism of Figure 13 move to provide forward motion for the PLAY/RECORD function?

19. In the PLAY/RECORD position the take-up reel rotates at constant speed. True or False?

20. The pinch roller and capstan drive the tape in the fast forward mode. True or False?

21. How is excessive head wear eliminated during rewind and fast forward?

22. List two methods of changing the speed in a tape recorder.

23. During playback or record, the take-up reel motor in Figure 18 receives full voltage. True or False?

24. What are the motor voltage conditions in the circuit of Figure 18 during rewind?

25. The brake in Figure 19 is released when the solenoid is (a) energized, (b) de-energized.

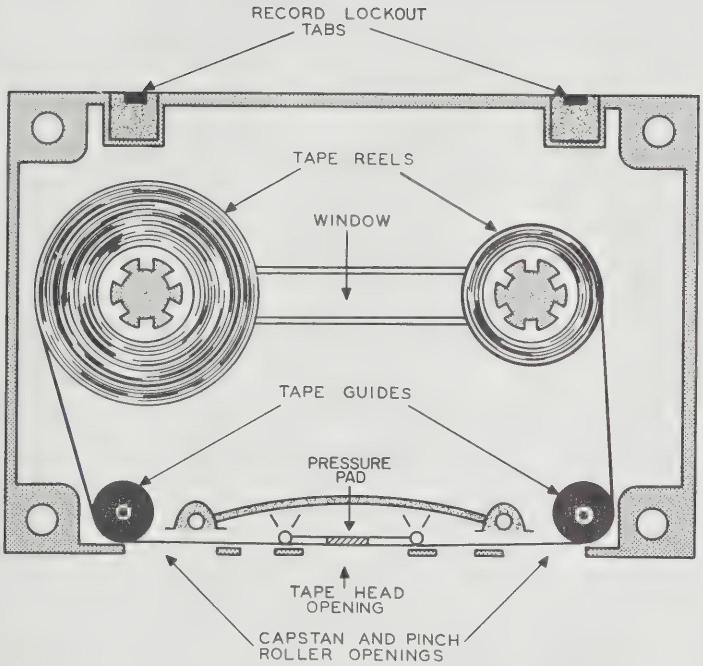


Figure 21

Cassette Recorders

Figure 21 shows the inside of a typical tape cassette. The tape is wound on small hubs, with the cassette top and bottom shells holding the tape in place. Openings in the cassette front permit the tape to contact the heads, capstan and pinch roller. The cassette is fairly small, about 4″ wide by $2^1/_2$″ deep by about $^3/_8$″ thick. Depending upon the thickness of the tape, the cassettes hold from 200 to 600 feet of tape. The tape used is 0.5, 0.3 or 0.25 mil thick prestretched $^1/_8$″ wide polyester. The 300-ft. reel provides 30 minutes on each side at $1^7/_8$ ips while the 600-ft. reel provides 1 hour of recording on each side. The small size of the cassette and the associated recorder makes for a compact portable recorder. The window in the cassette, along with a scale on the cassette, indicates the amount of tape or time left.

Figure 22 shows the general layout of a cassette tape transport mechanism. The cassette is inserted over the mechanism so that the projections on the reel turntable spindles engage the teeth in the cassette reels. The guide posts pass through appropriate holes in the cassette to hold it in position. The capstan also passes through a hole in the case so that the tape is between it and the pinch roller. During recording and playback, the heads move forward and contact the tape. Note that the pressure pad is built into the cassette. Along with the movement of the heads, the pinch roller moves forward to press the tape against the capstan. A belt and pulley arrangement like that of the reel-to-reel deck operates the supply and take-up reels.

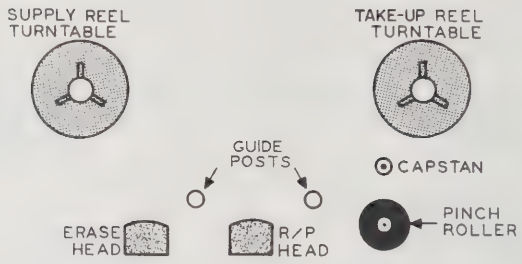


Figure 22

Prerecorded tapes are popular with cassette recording systems. To prevent accidental erasure of such tapes, record lockout tabs are located at the rear of the cassette as shown in Figure 21. If these tabs are broken out, a pin on the transport senses their absence and prevents recording. To prevent unintentional recording on any tracks of the cassette, a second lockout tab is provided for when the cassette is flipped over.

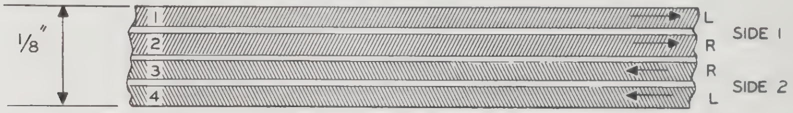


Figure 23

Figure 23 shows the track arrangement for the $^1/_8''$ cassette tape. Four tracks are employed for stereo operation. Note that adjacent tracks are used for the two stereo channels, left (L) and right (R), as compared to the staggered four-track arrangement used on conventional $^1/_4''$ tape. The adjacent track setup of Figure 23 makes stereo tapes compatible with monaural recorders. Monaural cassette recorders use half-track heads. Therefore, tracks 1 and 2 provide a monaural signal in one direction, and tracks 3 and 4 provide a monaural signal in the opposite direction.

High-Fidelity Cassette Recorders

Cassette recorders have had many improvements made in their designs recently, and as a result, some very high-quality machines are presently available. Wow and flutter in the mechanisms are now as low as 0.07%, which is equal to that of high-quality reel-to-reel tape decks.

Top-quality cassette recorders have signal-to-noise ratios of better than 50 dB. Most top-quality cassette recorders also include Dolby-type B circuitry, which further improves the signal-to-noise ratio by an additional 6 to 10 dB.

In addition to a cassette recorder, the above unit includes an AM and FM receiver.
Bell and Howell Photo

Improved types of recording tape are available that permit cassette recordings to approach the frequency range of recordings made on top-quality reel-to-reel decks. Low-noise tape and high-output low-noise tape permit flat response to beyond 14 kHz, and chromium dioxide tape extends response to beyond 16 kHz. These new tape types require different record and playback equalizations to obtain this extended response. Most top-quality cassette units therefore provide different switch-selected equalization curves.

For even better performance, cassette machines are available that employ dual capstan or servo-controlled drive mechanisms. Some very expensive units contain a separate playback headgap to permit monitoring during recording.

Cartridge Machines

Tape cartridge players are widely used in automobile music systems and are becoming popular in home-entertainment music systems. The tape cartridge is much different than the tape cassette. The tape cartridge contains only one tape reel, and the tape is connected to form an endless loop. The tape cartridges use $^1/_4''$ tape, and both four- and eight-track stereo arrangements are employed.

Figure 24 shows the three basic cartridge types. In all types, the tape unwinds from the center and returns to the outer perimeter of the reel. The type of cartridge shown in Figure 24A is referred to as the FIDELIPAC cartridge. This is generally a four-track stereo arrangement. The tape head contacts the tape through a hole in the cartridge. Another hole permits entry

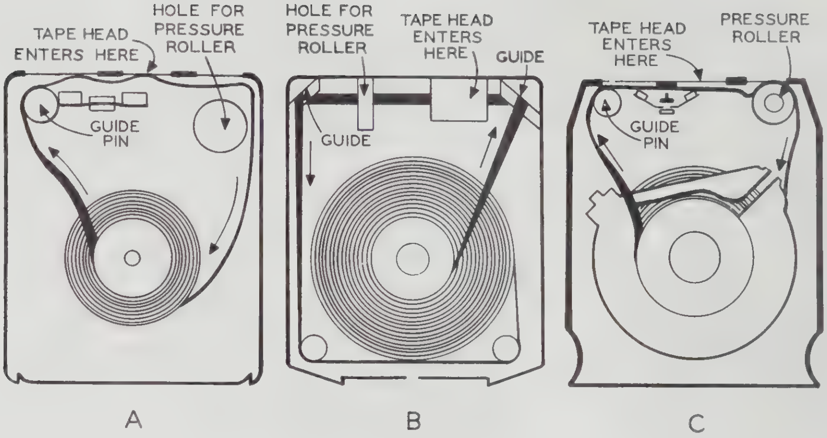


Figure 24

of the pinch roller for the capstan drive system. Figure 24B shows the ORRTRONIC cartridge. It is similar to the one in Figure 24A except that the tape moves in the opposite direction. Figure 24C shows the LEAR-JET cartridge, which is an 8-track stereo arrangement, and probably the most popular. In general, the three cartridge types are not compatible and must be used on their own types of machines.

The tape transports used with cartridge systems are much simpler than those used with conventional reel or cassette systems. Since there is only one tape reel, there is only one reel turntable. Due to the endless loop arrangement, no provisions are generally made for rewinding or fast forward. This eliminates all the belts and pulleys associated with that type of arrangement.

The most complex portion of the cartridge deck is the head positioning mechanism. In the four- and eight-track systems, the tape head is moved up and down to play the various tracks. Figure 25 shows a typical head positioning arrangement. The tape head is attached to a transfer pin which rides on a stepped cam. Each time the solenoid is activated, it rotates the cam and moves the head up or down.

Switching from one set of tracks to another is accomplished manually or automatically. For manual selection, a pushbutton activating the solenoid will change channels. Automatic selection is accomplished by placing a conductive strip on the tape near the end. When the sensing switch is closed by the conductive strip, the solenoid is activated to change channels. Since the tape is an endless loop its direction does not have to reverse. All tracks are recorded in the same direction.

Eight-track cartridges are also used for quadraphonic, or four-channel, prerecorded tapes. A four-channel playback head is used in these machines.

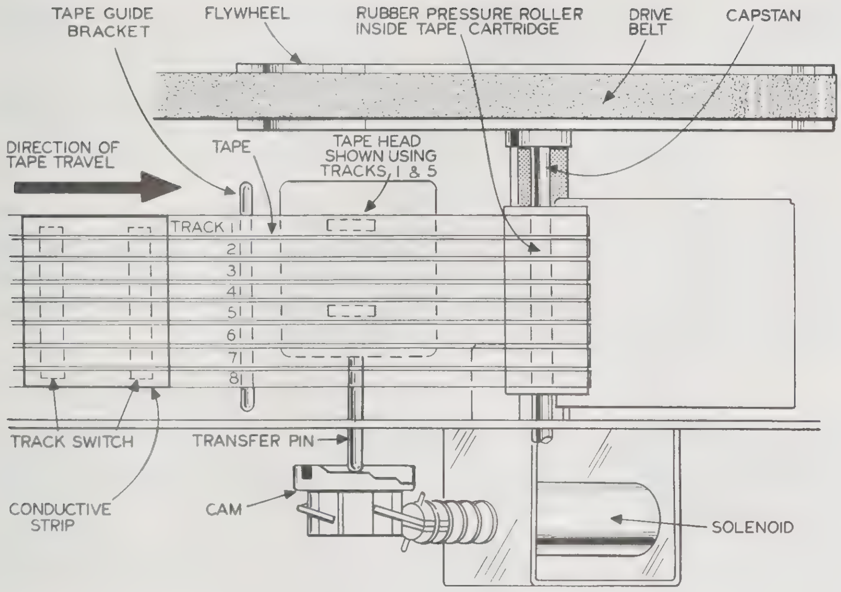


Figure 25

The four output signals of the heads go to four preamplifiers whose output signals drive four power amplifiers. The power amplifier output signals drive four speaker systems. These tapes contain two four-channel programs. Regular eight-track cartridges contain four programs of two-channel stereo.

ADJUSTMENTS AND PREVENTATIVE MAINTENANCE

Proper preventative maintenance can keep a tape recorder operating correctly for years. All pulleys, slides and levers should be lubricated with the recommended lubricants. Generally, a high-quality grease is used on the slides and levers, and a good-quality motor oil can be used to lubricate pulley shafts. Be certain that no lubricant gets on the pulley grooves or belts. This could cause slippage and speed variations. Also, avoid extensive lubrication. Accumulations of grease and oil can collect dust and dirt, causing improper operation. Grease and oil can be removed with a clean lint-free rag saturated with alcohol. Be careful when using cleaning solvents, as some of them can damage belts, rubber pulley rims and the tape heads.

When working on the tape transport mechanism, avoid using tools that are magnetized. You might magnetize a tape guide or some other part over which the tape passes. This could cause an increase in noise of the recorded signals. It is a good idea to demagnetize all the parts over which the tape passes with a demagnetizing tool. A demagnetizer is an ac-operated electromagnet. It is brought near the part to be demagnetized. Power is applied to the demagnetizer; it is brought in close proximity to metal parts; and then slowly withdrawn and turned off. Demagnetization of the tape heads, guides, etc., should be performed at regular intervals to assure good performance.

The belts, rubber tire pulleys and pinch roller are all subject to wear, and should be replaced as necessary. Stretched belts can cause slippage and speed variations. Flat spots on pulleys and the pinch roller can cause a thumping sound as well as speed variations. The pinch roller is especially important, since it drives the tape along with the capstan.

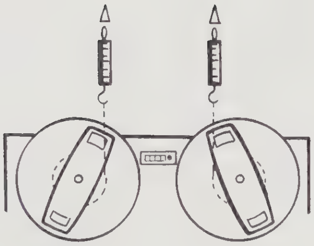


Figure 26

Many recorders require reel tension adjustments after periods of extensive use. The tension must be correct to prevent tape spilling or breakage, and to provide even winding. Since the adjustment procedures vary, consult the manufacturers' literature. In general, the tension, or torque, is determined with spring scales, as shown in Figure 26. On units with separate reel motors, the tension is adjusted by varying the reel motor voltages. On belt drive units, slip clutch or belt drive tension is adjusted.

One common problem is tape breaking or spilling when the unit is stopped, especially when in the fast forward or rewind modes. This is generally caused by misadjustment of the reel turntable brakes. Consult the manufacturers' literature for correct adjustment procedures.

HEAD CLEANING

A common problem is an accumulation of oxide and dirt on the tape heads, guides and other parts of the tape transport. Oxide accumulations on the capstan can cause speed variations. On the tape head, an accumulation of oxide can cause reduced output or distortion, and in severe cases, no recording or playback.

All parts of the transport that contact the tape should be cleaned at regular intervals. A cotton swab, dipped in alcohol or a solvent made for tape recorders, can be used to clean the various parts. DO NOT use carbon tetrachloride on the tape heads, as it can cause permanent damage. On units equipped with a switch operated by a foil sticker on the tape, be certain that the switch surfaces are clean.

Oxide and dirt accumulation is often a major cause of trouble in automotive eight-track players. The tape used in the endless loop cartridge is lubricated

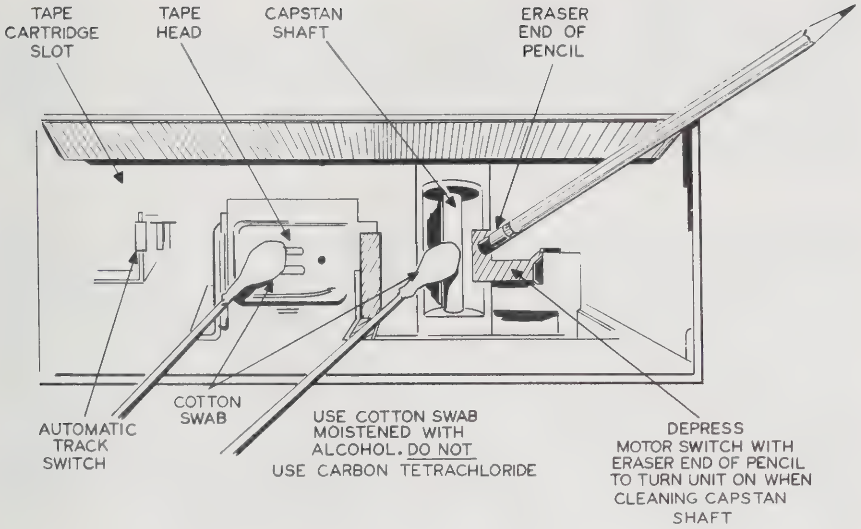

TAPE CARTRIDGE SLOT
TAPE HEAD
CAPSTAN SHAFT
ERASER END OF PENCIL
AUTOMATIC TRACK SWITCH
COTTON SWAB
USE COTTON SWAB MOISTENED WITH ALCOHOL. DO NOT USE CARBON TETRACHLORIDE
DEPRESS MOTOR SWITCH WITH ERASER END OF PENCIL TO TURN UNIT ON WHEN CLEANING CAPSTAN SHAFT

Figure 27

to prevent friction in the cartridge. Accumulations of this lubricant and oxide clog up the transport. Cotton swabs dipped in alcohol can be used to clean the heads, guides, etc. This can be done without disassembling the unit, as shown in Figure 27. When cleaning the capstan, turn on the motor by depressing the motor switch with the eraser on a pencil.

HEAD ALIGNMENT

For proper operation, the tape head must be aligned with the tape. Figure 28 shows various tape head adjustments. Azimuth, or skew, is the angle of the

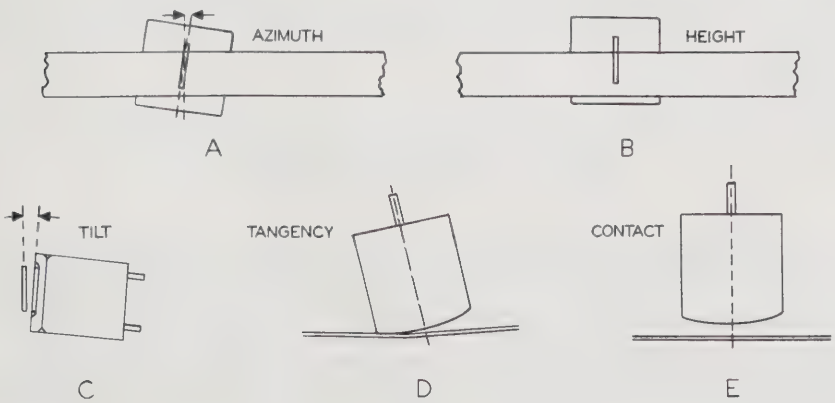


Figure 28

headgap with respect to a line perpendicular (90°) from the tape edge, as shown in Figure 28A. If the azimuth is incorrect, the output will be reduced. The height adjustment shown in Figure 28B is especially important in four- and eight-track systems. If the height is not correct, information from one track will be picked up by the headgap for the other track.

The tilt adjustment shown in Figure 28C is important for two reasons. If the tilt is great enough, one of the channels in a stereo system may not be reproduced at all, as the tape track must actually contact the head for proper operation. Tilt can cause uneven tape head wear. This can cause a reduction of high-frequency response and output. The tangency adjustment in Figure 28D also controls tape head wear. If it is not correct, one side of the head will wear more than the other. Although the tape is often held against the head by a pressure pad, it should still contact the tape head when the pressure pad is removed. This is the contact adjustment shown in Figure 28E. Poor contact can cause distortion and reduced output.

The life of a tape head is determined by the gap wear. As the gap wears, it becomes wider and the frequency response drops off. A magnifying glass or low-power microscope can be used to inspect the gap. If the wear is very uneven or if the gap has become ragged, the head should be replaced. For best head life, the head should be adjusted properly and cleaned often.

The tilt, tangency and contact adjustments shown in Figure 28 can usually be adjusted by eye. On some units, these may be fixed adjustments. Azimuth and height can best be adjusted with the aid of a test tape. The test tape for azimuth contains a continuous high-frequency signal. Azimuth is adjusted for maximum output of the test signal from the recorder. For the height adjustment, the alignment tape should contain different signals on the various stereo tracks. The tape head height is then adjusted to obtain the proper signal for each channel. Due to the small track widths, this adjustment is fairly critical on eight-track and cassette units. Follow the manufacturers' directions on tape head adjustments, as well as those provided with the alignment tape.

BIAS ADJUSTMENT

The high-frequency bias should be checked if suspected of malfunctioning, and adjusted if necessary. Replacements of the tape head or bias oscillator components may also require bias adjustment. The bias adjustment procedure may vary somewhat for different manufacturers. The adjustment is very important, and if not made properly, can cause distortion and poor performance.

An example of a bias adjustment procedure can be shown with the circuit of Figure 9. To adjust the bias on this unit, the record/playback head is replaced with a 100-ohm load resistor. The setting of the bias adjustment potentiometer, R_{224}, is varied to obtain 21.5 mV (.0215V) across the 100-ohm load resistor. Remember that the bias signal is of a high frequency, typically 80 kHz, and an AC VTVM must be used to measure it. An accurately calibrated oscilloscope can also be used. It is a good idea to use a scope to check the bias oscillator waveshape. Distortion in the bias signal can cause distortion in the recorded signal. Some manufacturers also specify a bias frequency adjustment, but this is not common practice.

The recording signal level is also important and this is why VU meters are provided. The calibration on the VU meters should also be checked. In the unit of Figure 9, a 1.5 mV (.0015V) signal is applied to the mic input, and the VU meter calibration control R_{217} is set so that the meter reads 0 VU. During recording, the level is set so that peaks do not exceed 0 VU.

TAPE RECORDER TROUBLESHOOTING

Since a tape recorder or tape deck is both electronic and mechanical, the first step in the troubleshooting procedure is to determine whether the trouble is mechanical or electrical. As always, begin with a thorough visual inspection. Make certain that the heads are clean, and all accumulations of oxide have been removed from the tape guides, switches, capstan, etc. If there is evidence of overheating or if the unit blows fuses, correct this problem before operating the unit.

Try to obtain the manufacturer's service manual for the unit being checked. All of the necessary adjustment procedures, as well as troubleshooting information, are included in the manual. The manual will also list any special tools or gauges that are required for servicing the recorder.

To illustrate the basic troubleshooting procedure for tape recorders, we will present a number of typical symptoms, the corresponding faults, and the necessary corrective steps.

Unit Completely Inoperative, Motor Does Not Run.

Power is not reaching the unit.—Check the line cord, fuse and on-off switch. This can best be done with an ohmmeter. On many units, the on-off switch is operated by a lever or pushbutton. Check to see that the mechanism is operating the switch.

Capstan Does Not Revolve, Motor and Amplifier OK.

The capstan belt is broken or not in place, or the motor pulley is loose.—Check the capstan belt, the motor pulley and capstan flywheel. Grease or oil on the belt or pulley can cause slippage. Clean with alcohol.

On units with a separate capstan motor, make sure that the capstan motor is operating. A separate capstan motor generally employs a phase shifting capacitor. Check this capacitor if power is reaching the motor and it is not operating. Note that this capacitor is a nonpolarized unit, and it must be replaced with the same type.

No Take-Up of Tape.

The take-up reel drive system is not operating.—Check the belts and pulleys which drive the take-up reel turntable. Make certain that the idler wheel contacts the take-up reel turntable and that the take-up reel brake is released. The mechanism may need adjusting. Grease or oil on the belts and pulleys can cause slippage. Clean with alcohol.

On units equipped with separate reel motors, check that the reel motor is receiving the correct voltage. These motors, like the capstan motor, may employ phase shifting capacitors. If voltage is reaching the motor and it does not run, check the capacitor. The units employing separate reel motors generally use solenoid operated brakes. Make sure that the brake is releasing and is properly adjusted.

No Rewind of Tape.

The rewind reel drive system is not operating.—Check the belts and pulleys which drive the rewind reel turntable. Be certain that the idler wheel contacts the rewind reel turntable and that the reel brakes are released. The mechanism may need adjusting. Clean the belts and pulleys with alcohol if they are slipping.

Tape Does Not Move When Record Or Play Function Is Selected.

The pinch roller is not pressing the tape against the capstan or the reel brakes are not releasing.—Check that the pinch roller is pressing the tape against the capstan. Also make sure that the reel turntable brakes are releasing. It may be necessary to adjust the linkages which operate the pinch roller and reel brakes.

On units with separate reel motors, the pinch roller, as well as the reel brakes, are solenoid operated. Make certain that power is reaching the solenoids. It may be necessary to adjust the solenoid travel.

Tape Breakage Or Spillage.

Improper reel brake adjustment.—Refer to the manufacturers' specifications on brake adjustments. Check that the brakes are activated when the various functions are selected.

On units that have separate reel turntable motors, be sure that the motors are receiving the proper voltages. It may be necessary to adjust reel motor voltage to obtain correct reel motor torque.

No Recording Or Playback Audio, Tape Transport Functions Normally.

The recording and playback amplifiers or the tape head are defective.—The recording and playback amplifiers can be checked in the same manner as a regular hi-fi/stereo amplifier. Either signal injection or signal tracing methods can be used.

Place the unit in the playback mode and use a screwdriver or audio generator to inject a signal at the volume control. If an output is obtained, the power supply and the stages following the volume control are operating properly. You can then inject a test signal in the stages that precede the volume control, working from the volume control back toward the tape head. Once the defective stage is found, use voltage and resistance tests to locate the defective component.

If the entire amplifier is functioning properly, check the tape head for continuity with an ohmmeter. An open or short circuit would cause the head to be inoperative. A unit that employs the same head for playback and record uses a switching arrangement. Use an ohmmeter to make sure the switch is operating properly. Since the ohmmeter passes a dc current through the head, the head will have to be demagnetized to restore proper operation.

With units that use separate recording and playback amplifiers and separate recording and playback heads, the trouble is probably in the power supply. Some units may have a regulator circuit in the power supply. A voltmeter can be used to check the operation of the supply, and an ohmmeter used to locate a defective component.

The tape must be closely held against the head for proper operation during record and playback. Make certain that the pressure pads press the tape against the heads on those machines that use pressure pads. It is also a good idea to use a test tape known to be good, rather than record a tape on the unit and then use it for testing the playback system.

Playback Normal, No Recording.

The recording amplifier, record head or bias oscillator are not functioning properly.—Many units employ some common circuitry on record and playback. On those machines, the common circuitry is all right if the unit operates properly on playback. You can confine further tests to the recording amplifier and the bias oscillator. The oscillator output can be used to signal trace the recording amplifier. When a combination record/playback head is employed, a defect in the head can be ruled out for this problem category, as it would affect both record and playback. Check the switches which change the head connections for record and playback.

With units employing separate record and playback amplifiers, you can perform signal injection or signal tracing steps in the record amplifier. Once the defective stage is located, you can perform voltage and resistance tests to locate the defective component.

No Playback, Recording Normal.

The playback amplifier, playback head or the switching circuits are defective.—Most tape recorders that have common recording and playback amplifiers use all the stages on record that are used on playback. For those recorders, such stages can be ruled out as problems for this

The photo above shows a typical tape head demagnetizer.
Courtesy Superscope Inc.

malfunction. This leaves the power amplifier or the switching arrangement on the playback head as possible causes of this trouble. The playback head and switching arrangement can be checked with an ohmmeter. The power amplifier can be checked by signal substitution or signal injection.

If the unit employs separate recording and playback amplifiers, you can check the playback amplifier by signal substitution or signal injection. Be sure to demagnetize the head if you use an ohmmeter to check the head's resistance.

Distortion On the Recording Signal.

Improper bias adjustment could be the cause of this malfunction. Refer to the manufacturers' literature on setting the high-frequency bias frequency and level. Make certain that the bias signal is not distorted.

If the bias is set properly, the trouble source is in the recording or playback amplifiers. The simplest method of locating distortion is to apply an undistorted signal from an audio oscillator to the amplifier, and trace the signal's path with an oscilloscope. Once the stage producing the distortion is located, voltage and resistance tests can be used to locate the cause of the defect. Distortion of this nature is generally a result of a shift in bias or a defective component in a feedback loop.

Poor Frequency Response On Record and Playback.

Improper bias adjustment or faulty head alignment are possible causes of this trouble.—Check the bias level adjustment, as previously explained. Also check the head alignment. Use an alignment tape to check azimuth of the head.

If the head alignment is correct, tests should be made on the amplifiers. A square-wave test signal provides a quick method of testing frequency response. Apply the square-wave test signal, and trace it through the amplifier stages with an oscilloscope. A rounded leading edge indicates a decrease in high-frequency response. Droop in the top and bottom of the square wave indicates a decrease in low-frequency response. A test signal of 1000 Hz will test both low- and high-frequency response of the amplifier.

No Erase.

Inoperative bias/erase oscillator or defective erase head.—The operation of the bias erase oscillator can be checked by measuring the erase signal level at the erase head. The erase head can be checked with an ohmmeter for an open- or short-circuit condition. Also check the switching circuit which turns on the bias/erase oscillator during record.

Stereo Recorder Troubles.

The problems described previously apply to both monaural and stereo recorders. With a stereo unit, there are two record-playback amplifier channels. Troubles may be confined to one channel or may be present in both channels. In any stereo system, the signal can be switched from one channel to the other to aid in locating the defect. The signal levels, voltage and resistance measurements in one channel can be compared to those in the defective channel to locate the trouble.

Head alignment is rather critical, and should be checked if one channel is working properly and the other is not. A test tape is almost a necessity for head alignment.

SUMMARY

The tape recorder consists of two separate sections, the tape transport and the record/playback amplifiers. The tape transport is basically mechanical in nature and subject to normal mechanical problems. Proper cleaning is important to the life of the tape heads. Careful head alignment is essential. The tape heads, tape guides and other parts that come in contact with the tape should be periodically demagnetized to remove any stray magnetic fields which could cause noise on the tape.

The amplifier circuits associated with a tape recorder are similar to those employed in conventional hi-fi/stereo systems. The only major differences are the addition of a bias/erase oscillator and a recording amplifier stage. Conventional signal tracing or signal injection tests can be used to locate sources of trouble.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

CASSETTE AND CARTRIDGE TRANSPORTS

CASSETTE RECORDERS

HIGH-FIDELITY CASSETTE RECORDERS

CARTRIDGE MACHINES

ADJUSTMENTS AND PREVENTATIVE MAINTENANCE

HEAD CLEANING

HEAD ALIGNMENT

BIAS ADJUSTMENT

TAPE RECORDER TROUBLESHOOTING

26. In a cassette tape transport, the tape is pushed against the heads by a pressure pad. True or False?

27. Stereo cassettes can be played on a monaural recorder. True or False?

28. The tape cartridges shown in Figures 24A and 24B can be played on the same system. True or False?

29. Tape cartridge transports usually have fast forward and rewind functions. True or False?

30. How are the channels switched in an 8-track tape system?

31. One of the best solvents for clean tape recorders is ________________.

32. Why should parts of the tape transport that contact the tape be demagnetized?

33. What would be the result of an improperly adjusted reel turntable brake?

34. A good tape head cleaner is carbon tetrachloride. True or False?

35. Tangency error in the tape head alignment can cause excessive head wear. True or False?

36. Explain how an azimuth adjustment is made.

37. Explain how a height adjustment is made.

38. If the drive motor operates but the capstan does not revolve, what would you check?

39. What is the most probable result of reel turntable brake misadjustment?

IMPORTANT DEFINITIONS

BIAS—A high-frequency ac signal added to the recording signal to avoid the nonlinear characteristics of the recording medium. On some small portable recorders, dc bias is used.

DROPOUT—A momentary loss of signal due to imperfections in the oxide coating on the tape.

EIGHT TRACK—A recording arrangement where eight separate signals can be recorded. When recording stereo, this gives four stereo signals.

FOUR TRACK—Also called "quarter track."—A recording arrangement where four separate signals can be recorded. This is generally used for stereo recording where a pair of tracks is used for each stereo signal.

FULL TRACK—A recording arrangement where the entire width of the tape is used for the signal.

HALF TRACK—A recording arrangement where the signal is recorded on $^1/_2$ of the tape width. This allows two signals to be recorded on the tape.

HEAD—The ring-shaped electromagnetic assembly in a tape recorder, used to record and reproduce signals on magnetic tape.

PRINT THROUGH—Transfer of the magnetic field from one layer of tape on a reel to another.

TAPE TRANSPORT—The mechanism which moves the tape past erase, playback and record heads.

PRACTICE EXERCISE SOLUTIONS

1. iron oxide
2. head
3. Headgap size and tape speed.
4. (d) 15 ips.
5. Bias is a high-frequency ac signal, linearly mixed with the recording signal to eliminate distortion.
6. 75 kHz.—The bias signal frequency should be at least five times the highest recording signal frequency.
7. False—Some small portable recorders employ a dc bias.
8. True
9. The bias oscillator supplies the erase signal as well as the bias signal for recording.
10. (a) increases the high-frequency response.
11. S_{406} selects the proper components for the feedback network between Q_{202} and Q_{203} to provide the correct frequency response for the various tape speeds.
12. The record amplifier Q_{204}.
13. 0
14. Half-track recording permits twice as much material to be recorded on a given reel of tape.
15. Four.—A pair of tracks is required for each stereo selection.
16. boost; attenuate
17. The capstan tape drive provides constant tape speed.
18. The pinch roller presses the tape against the capstan and the take-up pulley presses against the take-up turntable.
19. False—The take-up reel speed depends upon the amount of tape on the take-up reel.

PRACTICE EXERCISE SOLUTIONS (Continued)

20. False—The fast forward pulley drives the take-up reel turntable when in the fast forward mode.

21. The tape is lifted from the heads during fast forward and rewind.

22. Belt drive tape transports often employ a stepped motor pulley and a shift fork to move a pulley drive belt. Multiple motor transports often employ a capstan motor with separate windings for each speed.

23. False—The take-up reel motor receives approximately one-half normal voltage during playback and record.

24. During rewind, the supply reel motor receives full voltage, and the take-up reel motor receives a small voltage to provide holdback tension.

25. (a) energized.

26. False—The pressure pad is located in the cassette and the heads are pushed against the tape and pressure pad.

27. True—The tracks are adjacent to provide compatibility.

28. False—The tape runs in the opposite direction in these two cartridges.

29. False—The endless loop arrangement is not practical for rewinding or high-speed operation.

30. The tape head is moved vertically for channel selection.

31. alcohol

32. Demagnetization removes stray magnetism which could increase the noise level on the tape.

33. An improperly adjusted reel turntable brake could cause tape spillage or breakage.

34. False—Carbon tetrachloride can damage the tape head. Use only alcohol or a solvent especially made for cleaning tape heads.

35. True

36. The azimuth adjustment is made with a test tape recorded with a high-frequency test signal. The head azimuth is adjusted for maximum output.

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4141 BELMONT AVENUE, CHICAGO, ILLINOIS 60641

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7545A
EXAMINATION CHECK SHEET

7545A

1. A - THE HIGH-FREQUENCY RESPONSE OF A MAGNETIC TAPE RECORDER IS INCREASED BY -- DECREASING HEADGAP SIZE.
The high-frequency response is determined by the gap size and the tape speed. Decreasing the headgap and/or increasing the tape speed will increase the high-frequency response.

2. D - THE TYPE OF BIAS NORMALLY USED IN MAGNETIC TAPE RECORDING IS A -- HIGH-FREQUENCY AC SIGNAL.
Most good tape recorders employ a high-frequency bias signal. Some of the lower priced units may employ a dc bias system.

3. A - TO COMPENSATE FOR THE PROPERTIES OF MAGNETIC RECORDING, THE PLAYBACK AMPLIFIER MUST -- BOOST THE LOW FREQUENCIES AND ATTENUATE THE HIGH FREQUENCIES.
The output of the tape head rises as frequency increases. To provide a flat frequency response, the playback amplifier must provide an opposite response.

4. D - Q_{308} AND Q_{309} IN THE CIRCUIT OF FIGURE 9 FORM A -- PUSH-PULL OSCILLATOR.
This particular oscillator circuit arrangement is called a push-pull oscillator, as one transistor conducts more when the other conducts less.

5. D - IF THE BIAS OSCILLATOR IN THE CIRCUIT OF FIGURE 9 SHOULD BECOME INOPERATIVE, -- DISTORTION OF THE RECORDED SIGNAL WOULD OCCUR.
With no bias signal, the tape would not be erased, and the signals recorded on the tape would be distorted.

6. A - IF Q_{203} IN THE CIRCUIT OF FIGURE 9 DEVELOPS A BASE-TO-EMITTER SHORT, -- THE UNIT WILL NOT RECORD OR PLAY BACK.
A base-to-emitter short will make the base and emitter voltage of Q_{203} the same. Since Q_{203} is used on both record and playback, these functions will be inoperative.

7. B - THE MAJOR ADVANTAGE OF THE CAPSTAN DRIVE SYSTEM IS -- CONSTANT TAPE SPEED.
The capstan drive system provides constant tape speed.

8. A - IN THE REEL MOTOR SYSTEM OF FIGURE 18, IF R_3 OPENS -- THE TAPE WILL NOT WIND TIGHT ON REWIND.
With R_3 open, no hold-back tension will be provided by the take-up reel motor.

9. B - IF THE CONDUCTIVE TAPE STICKER IN AN EIGHT-TRACK STEREO CARTRIDGE IS MISSING -- THE HEAD POSITIONING MECHANISM WILL NOT BE ACTUATED.
The conductive tape sticker is used to activate the head positioning mechanism, and if it is missing, the head will not shift at the end of each tape program.

10. D - TAPE SPILLAGE OR BREAKAGE IS GENERALLY CAUSED BY A DEFECTIVE -- TAPE REEL BRAKE.
Defective or improperly adjusted reel brakes can cause tape breakage or spillage when changing the recorder from one function to another.

PRACTICE EXERCISE SOLUTIONS (Continued)

37. The height adjustment is made with a test tape having separate signals recorded on the various tracks. The height is adjusted to obtain the desired signal on the correct channel.

38. If the capstan does not revolve, check the capstan belt and motor pulley. If oil or grease is causing slippage, clean the parts with alcohol.

39. Tape breakage or spillage, especially when switching from fast forward or rewind to stop.

QUESTIONS

IMPORTANT—These instructions **MUST** be accurately followed to avoid loss, or errors in grading.

Indicate your answer on this sheet by filling in the box for the most correct answer to each question, as illustrated in the example below.

When all questions have been answered, place the answer card in the proper position to line up the boxes on the card with the boxes on the sheet.

Next, copy the complete lesson code into the space provided on the card, and fill in the answer boxes to correspond with those previously filled in on this sheet.

Before mailing, be certain your correct student number, name and address appear on the card.

LESSON CODE
7545A

Example: Heat is usually associated with
A ☐ B ☐ C ■ D ☐
(A) weight. (B) color.
(C) temperature. (D) size.

1. A ☒ B ☐ C ☐ D ☐
The high-frequency response of a magnetic tape recorder is increased by
(A) decreasing headgap size. (B) decreasing tape speed. (C) increasing headgap size. (D) decreasing tape thickness.

2. A ☐ B ☐ C ☐ D ☒
The type of bias normally used in magnetic tape recording is a
(A) dc current applied to the playback head. (B) dc current applied to the record head. (C) low-frequency ac signal. (D) high-frequency ac signal.

3. A ☒ B ☐ C ☐ D ☐
To compensate for the properties of magnetic recording, the playback amplifier must
(A) boost the low frequencies and attenuate the high frequencies. (B) attenuate the low frequencies and boost the high frequencies. (C) attenuate both the low and high frequencies. (D) boost both the low and high frequencies.

4. A ☐ B ☐ C ☐ D ☒
Q_{308} and Q_{309} in the circuit of Figure 9 form a
(A) Colpitts oscillator. (B) push-pull audio amplifier. (C) Hartley oscillator. (D) push-pull oscillator.

5. A ☐ B ☐ C ☐ D ☒
If the bias oscillator in the circuit of Figure 9 should become inoperative,
(A) playback of a previously recorded tape would not be possible. (B) tape erasure would not be affected. (C) very little if any distortion would occur. (D) distortion of the recorded signal would occur.

6. A ☒ B ☐ C ☐ D ☐
If Q_{203} in the circuit of Figure 9 develops a base-to-emitter short,
(A) the unit will not record or play back. (B) recording will not be affected. (C) playback will not be affected. (D) the base and collector voltage will measure the same.

7. A ☐ B ☒ C ☐ D ☐
The major advantage of the capstan drive system is
(A) variable speed operation. (B) constant tape speed. (C) good frequency response. (D) fast rewind possible.

8. A ☒ B ☐ C ☐ D ☐
In the reel motor system of Figure 18, if R_3 opens
(A) the tape will not wind tight on rewind. (B) the rewind reel motor will run too slow on rewind. (C) the take-up reel motor will receive too much voltage during rewind. (D) the rewind motor will receive too much voltage during fast forward.

9. A ☐ B ☒ C ☐ D ☐
If the conductive tape sticker in an eight-track stereo cartridge is missing
(A) the tape will not reverse. (B) the head positioning mechanism will not be actuated. (C) the tape will stop. (D) the tape cartridge will bind.

10. A ☐ B ☐ C ☐ D ☒
Tape spillage or breakage is generally caused by a defective
(A) pressure pad. (B) tape head. (C) tape reel. (D) tape reel brake.

SERVICING AM-FM/STEREO RECEIVERS

7550

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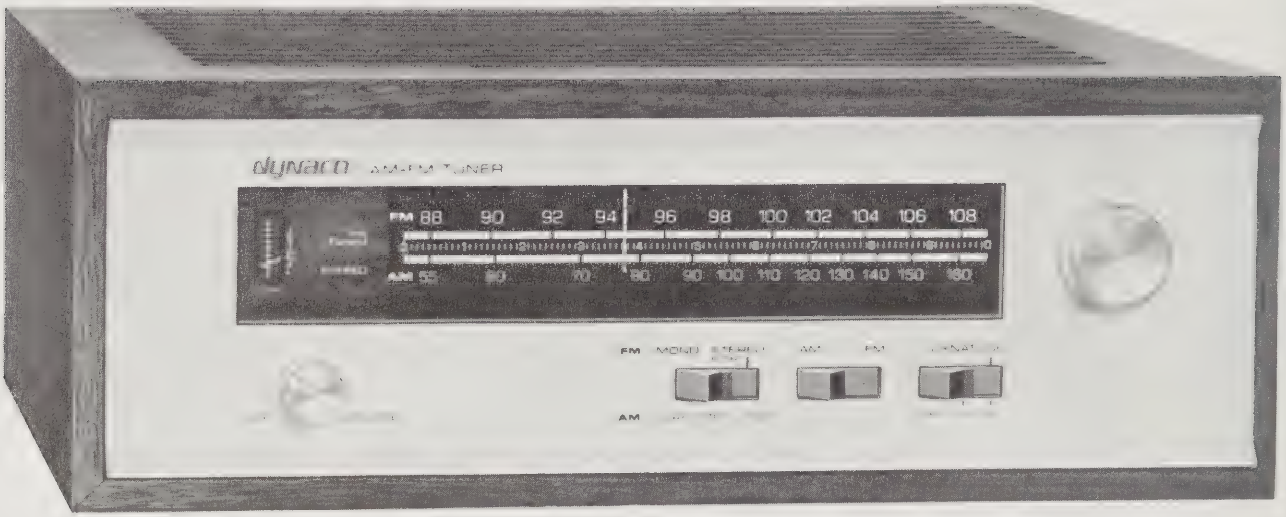
dynaco AM-FM TUNER
FM 88 90 92 94 96 98 100 102 104 106 108
AM 55 60 70 80 90 100 110 120 130 140 150 160
STEREO
FM MONO
AM FM
AM

This AM-FM/STEREO tuner combines a low noise front end with high Q ceramic i-f filters for high FM sensitivity and selectivity.

Courtesy Dynaco

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A fool beholds only the beginning of his
works, but a wise man takes heed to the
end.
The test of a first-rate work, and of your
sincerity in calling it a first-rate work,
is that you finish it.
—Arnold Bennett

SERVICING AM-FM/STEREO RECEIVERS

Most modern hi-fi stereo music systems include an AM-FM/STEREO receiver. Due to the large number of circuits that make up such a unit, they can appear to be quite complex. However, the individual circuits are not complex and the unit is easy to understand and service if it is taken one circuit at a time. As with any piece of electronic equipment, a thorough understanding of circuit operation is essential to rapid and efficient servicing. It is difficult to determine if a circuit is operating properly if you don't know how it should operate.

The basic servicing procedures used on AM-FM/STEREO receivers apply to the other parts of the hi-fi system as well as on broadcast AM and FM receivers. Dynamic tests such as signal injection or signal tracing are used to locate the defective stage. Static tests such as voltage and resistance measurements in the defective stage are used to locate the defective component or components.

Figure 1 shows a block diagram of one type of AM-FM/STEREO receiver. Two separate tuner circuits are used to select the desired AM or FM station. Each Tuner consists of an r-f amplifier, mixer and oscillator. The AM or FM i-f signal is then fed to a combination AM-FM I-F Strip. The i-f strip is generally arranged so that the first couple of stages amplify both the 455-kHz AM and the 10.7-MHz FM i-f signals. Since the AM signal levels are generally quite high, only a couple of stages are needed to bring the AM i-f signal level up to a usable level. It is also common for an AM-FM/STEREO receiver to have completely separate i-f stages. A conventional diode-type AM Detector demodulates the signal and applies the recovered audio to the audio amplifiers.

The FM i-f signal is applied to several more i-f stages with the last stage or two operating as limiters. The FM i-f signal is then demodulated in a separate FM Detector. Both ratio detectors and discriminators are used. On a stereo broadcast the output of the detector consists of a signal which represents the sum of the left and right channel audio signals as well as the stereo difference signal. The combination left and right audio signal could be applied to an audio amplifier and would produce a normal monaural output. However, when this signal is combined with the stereo difference signal in the stereo demodulator, the left and right audio signals are separated to form the stereo signal. The left and right audio signals are then applied to the right and left channel audio amplifiers.

When servicing any receiver, the first step is to isolate the trouble to a stage or group of stages. Once the defective stage has been found, you can perform the tests necessary in that stage to locate the defect.

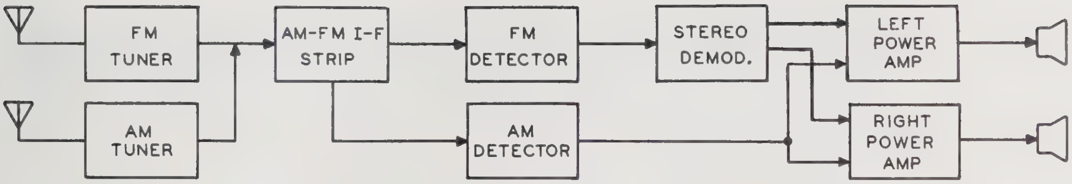


Figure 1

TUNER CIRCUITS

Figure 2 shows the schematic diagram of a typical AM tuner. The term **FRONT END** is often applied to such a tuner which consists of an r-f amplifier, mixer and local oscillator. The Loop Antenna and T_1 are tuned to the desired station frequency by C_{1A}. Provisions are also available for connecting a long wire external antenna to the circuit. Q_1 is an NPN transistor operated with its collector near ground potential. The negative supply is connected to the emitter through R_3 with C_3 bypassing the emitter. This "upside down" arrangement provides more stable operation and permits the use of both PNP and NPN transistors without separate power supplies. Bias for the Q_1 stage is supplied by the agc source through R_2. The agc source provides a negative voltage that increases as the signal strength increases. Since Q_1 is an NPN transistor, an increase in negative base voltage reduces base and emitter current, causing a reduction in gain. This method of reducing gain by reducing emitter current is called **REVERSE AGC.**

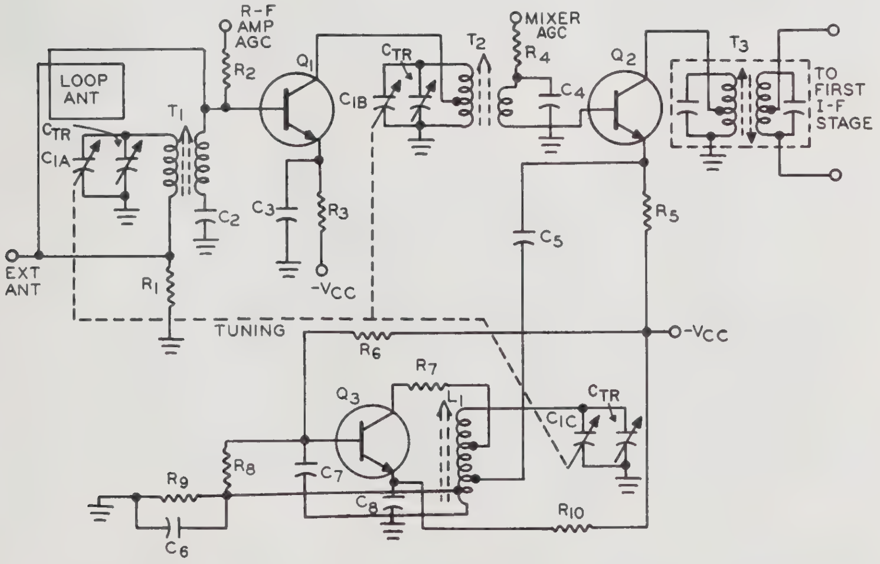


Figure 2

The tuned collector circuit of Q_1 is formed by the primary of T_2 and C_{1B}. The collector is tapped down on the primary of T_2 to provide the desired impedance match and keep circuit Q high. The secondary of T_2 couples the amplified r-f signal to the base of Q_2. Reverse agc bias is applied to the mixer base through R_4.

Q_3 and its associated components form a Hartley oscillator circuit which serves as the local oscillator. C_{1C} tunes L_1 to the desired frequency, 455 kHz above the incoming signal. C_5 couples the oscillator signal to the emitter of the mixer, Q_2. The tuned circuit, T_3, in the collector of Q_2 passes only the difference i-f signal.

Figure 3 shows the schematic diagram of a typical FM tuner or "front end." Q_1, a junction field effect transistor, forms the r-f amplifier. Field effect transistors are becoming very popular in r-f amplifiers. Under normal operating conditions, the gate is reverse biased. The input impedance of the JFET is then high, and it does not load down the tuned circuit. This circuit also reduces **CROSS MODULATION.** Cross modulation occurs when a strong signal modulates a weaker desired signal. Cross modulation often occurs in bi-polar transistors because the base circuit is forward biased and tends to be nonlinear.

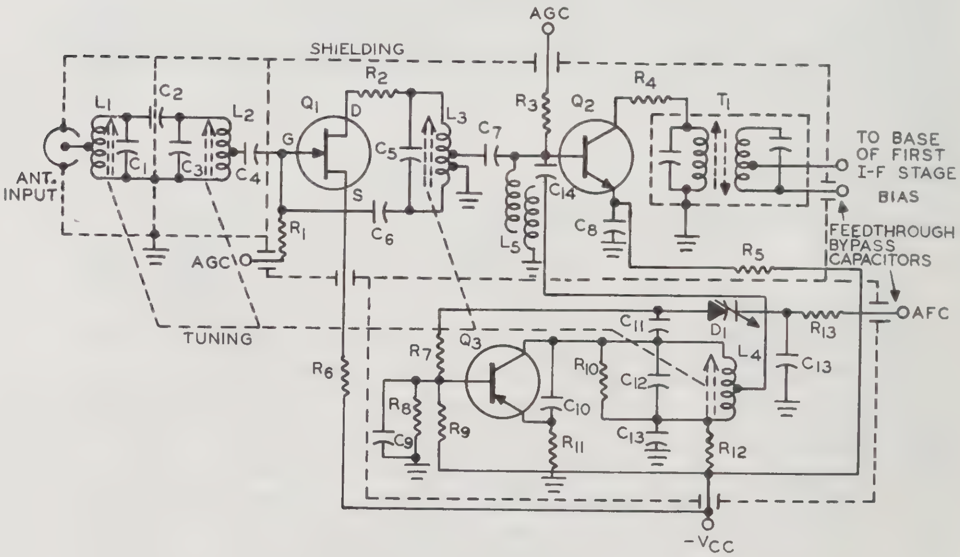


Figure 3

L_1, C_1, and L_2, C_3 form a double-tuned bandpass filter circuit to select the desired signal frequency. Note that L_1 and L_2 are not inductively coupled but capacitively coupled by C_2. Extensive shielding is employed to reduce undesirable inductive coupling as well as to prevent undesired radiation of the oscillator signal. Reverse agc is applied to the gate of Q_1 through R_1. Q_1 is operated "upside down" with the drain grounded through L_3 and the supply connected to the source through R_6. The Q_1 stage is neutralized by C_6. C_5 and L_3 form the tuned output circuit for Q_1. L_3 is tuned along with L_1, L_2 and oscillator coil L_4. In many FM receivers, front end tuning is not inductive, but is capacitive. This is achieved by either a ganged variable capacitor or varactor diodes.

Q_3, connected as a common-base oscillator, serves as the local oscillator. C_{12} and L_4 determine the frequency of oscillation. C_{10} provides the feedback to sustain oscillation. Voltage variable capacitance diode D_1 provides automatic frequency control. The capacitance of D_1 is controlled by the afc voltage derived from the FM detector. As the afc negative voltage reduces the reverse bias on D_1, the diode's capacitance increases, causing a decrease in frequency and vice versa.

The oscillator signal from a tap on L_4 is coupled to the base of the Q_2 mixer stage. T_1 in the collector circuit of Q_2 passes only the i-f difference signal to the i-f amplifier. Reverse agc is applied to the mixer base through R_3. L_5 is a 10.7-MHz trap which prevents any outside signals in the i-f range from getting into the mixer circuit and, in turn, into the i-f amplifier. If this were to occur, an interfering signal might appear across the entire FM band.

AM-FM I-F AMPLIFIERS

As mentioned earlier, many AM-FM/STEREO receivers employ a combination i-f amplifier that can amplify both the 10.7-MHz FM i-f signal as well as the 455-kHz AM i-f signal. Figure 4 shows a typical combination i-f amplifier along with the AM and FM detector circuits.

T_1 and T_2 are the i-f transformers in the collector circuits of the FM and AM tuner mixer circuits. The secondaries of the two transformers are connected in series and apply the signal to the base of the First I-F Amplifier, Q_1. Switch S_{1A} supplies power to either the AM or FM tuner so both are not operating at the same time. Placing the 10.7-MHz FM i-f transformer closest to the base and the 455-kHz AM i-f transformer closest to ground sets up the following conditions. As far as the 10.7-MHz FM i-f signals are concerned, the low reactance of the AM i-f transformer capacitor acts like a short to this signal. On the other hand, the very low inductance of the FM i-f transformer presents little opposition to the 455-kHz i-f signals. As a result, the circuit "appears" to have only one effective i-f transformer at each intermediate frequency.

The transistors in this i-f strip are operated "upside down," as were the transistors in the AM and FM tuners shown previously. With this arrangement, the collector loads are grounded and the supply voltage is applied to the emitter. The primaries of both i-f transformers are connected in series in the collector circuits of Q_1 and Q_2. The operation is the same as in the base circuit of Q_1.

AM

Let's trace the signal through the i-f amplifier, assuming that the AM tuner is operating. The AM i-f signal is coupled through T_2 to the base of Q_1. The output signal from Q_1 is coupled to the base of Q_2 through T_4. The voltage at the emitter of Q_1 is used as the agc voltage for the AM tuner mixer and r-f stages. Bias for the Q_1 stage is developed by the agc circuit consisting of D_3, R_{13} and C_{12}.

The output signal from Q_2 is coupled to the detector, D_4, and agc circuit through T_6. D_4 serves as a conventional diode AM detector. The filter network consisting of R_{14} through R_{16} and C_{13} through C_{16} removes the r-f from the demodulated audio signal. The audio signal is then applied to the audio amplifier through S_{1D}.

A negative agc voltage is developed by D_3 and applied back to the base of Q_1 through R_1 and R_5. An increase in signal level increases the negative agc voltage applied to the base of Q_1. This reduces the forward bias on Q_1, reducing Q_1 emitter current and circuit gain. A reduction in Q_1 emitter current causes an increase in the negative voltage at the emitter of Q_1. This increased negative voltage is also applied to the AM tuner mixer and r-f circuits to reduce their gain. D_2 isolates the mixer and r-f amplifier agc circuits. R_2 is adjustable so that the gain of the i-f amplifier can be set to the desired point.

The AM signal at the primary of T_6 is coupled through L_2 and C_{30} to the tuning meter circuit. L_2 and C_{30} form a 10.7-MHz trap. The AM signal is

This AM-FM/STEREO Receiver uses integrated circuits and crystal filters in the FM i-f amplifier.
Courtesy Heath Co.

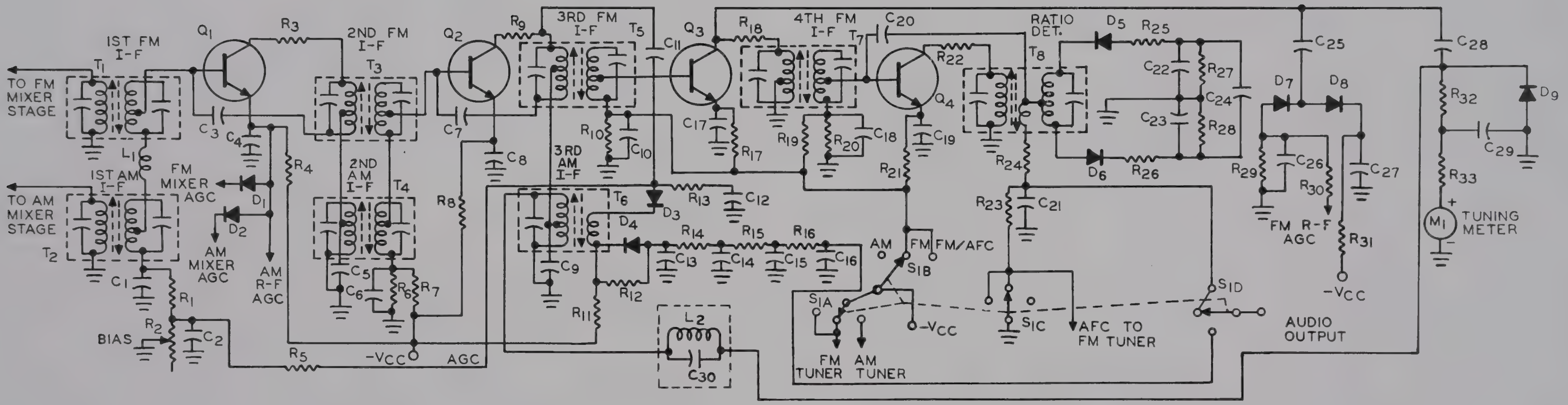

TO FM MIXER STAGE
T1
1ST FM I-F
Q1
R3
2ND FM I-F
T3
Q2
R9
3RD FM I-F
T5
C11
Q3
R18
4TH FM I-F
T7
C20
Q4
R22
RATIO DET.
T8
D5
R25
C22
R27
C24
C23
R28
D6
R26
C25
D7
D8
C26
R29
R30
C27
FM R-F AGC
R31
-VCC
C28
R32
D9
C29
R33
M1
TUNING METER
C3
C4
L1
FM MIXER AGC
D1
D2
R4
AM MIXER AGC
AM R-F AGC
1ST AM I-F
TO AM MIXER STAGE
T2
C1
R1
R2
BIAS
C2
R5
-VCC
AGC
C7
C8
R8
2ND AM I-F
T4
C5
C6
R6
R7
3RD AM I-F
T6
C9
R10
C10
D3
D4
R13
C12
R14
R15
R16
C13
C14
C15
C16
R12
R11
L2
C30
C17
R17
R19
R20
C18
C19
R21
R24
R23
C21
AM
FM
FM/AFC
S1B
S1A
-VCC
FM TUNER
AM TUNER
S1C
AFC TO FM TUNER
S1D
AUDIO OUTPUT

Figure 4

rectified by D_9 and the dc voltage applied to tuning meter M_1. As the receiver is tuned through a signal, the reading on M_1 will increase to a maximum at the point where the receiver is tuned exactly to the station carrier frequency.

FM

The FM signal follows a similar path through the first and second i-f stages. The 10.7-MHz signal at the collector of Q_2 is coupled through C_{11} to D_3. D_3 operates as a shunt rectifier and develops a negative agc voltage. This voltage is applied back to the base of Q_1 to control its gain. In turn, the emitter voltage of Q_1 is used as the mixer agc voltage in the FM tuner. D_1 isolates the FM mixer agc circuit from the other circuits connected to the Q_1 emitter. Due to the higher frequencies involved with FM operation, C_3 and C_7 provide neutralization for the Q_1 and Q_2 stages.

Due to the lower signal levels encountered in FM broadcast reception, more stages of amplification are required for FM than AM. T_5 couples the signal from the collector of Q_2 to the base of Q_3, the Third FM I-F stage. The output from the Q_3 stage is coupled through T_7 to the Q_4 Fourth FM I-F stage. The output of Q_4 is coupled through T_8 to a standard Ratio Detector circuit consisting of D_5, D_6 and their associated components. S_{1D} couples the audio output of the FM detector to the audio amplifiers and/or stereo demodulator unit.

During AM operation, S_{1B} removes the supply voltage from the Q_3 and Q_4 stages; and S_{1A} applies the supply voltage only to the AM tuner. When FM operation is selected, S_{1A} and S_{1B} apply power to only the FM tuner as well as to the Q_3 and Q_4 stages.

In addition to the audio signal appearing at the junction of R_{24} and C_{21}, a dc voltage appears at this point. This voltage is zero when the receiver is tuned right on the carrier frequency, producing an intermediate frequency at exactly 10.7 MHz. If the receiver tuning is either high or low, a positive or a negative voltage will appear at this point. This dc voltage is applied to the FM tuner afc circuit through R_{23} to provide automatic frequency control. The positive or negative afc voltage aids or opposes the reverse bias on the voltage variable capacitance diode (D_1 in Figure 3) to keep the local oscillator on the correct frequency. S_{1C} provides a position where this voltage is shorted to ground so the receiver can be tuned to an FM station without afc action.

The FM i-f signal at the collector of Q_3 is applied to the tuning meter circuit through C_{28}. D_9 rectifies this signal and provides the greatest deflection of M_1 when the receiver is tuned correctly.

The FM i-f signal at the collector of Q_3 is also applied to the agc rectifier circuit through C_{25}. D_7 and D_8 form a voltage doubler circuit which develops a negative agc voltage for the FM tuner r-f amplifier.

INTEGRATED CIRCUIT I-F AMPLIFIERS

Integrated circuit amplifiers are becoming very popular in FM i-f amplifiers. In addition, there is an increased use of crystal and ceramic filters in FM i-f strips in place of conventional LC circuits to shape the bandpass. Figure 5 shows an FM i-f amplifier employing both crystal filters and integrated circuits as well as transistors. There are many advantages to this type of circuit. The crystal filters provide more ideal flat-topped intermediate-frequency response and adjacent channel rejection. The integrated circuits provide high gain and have built-in limiting.

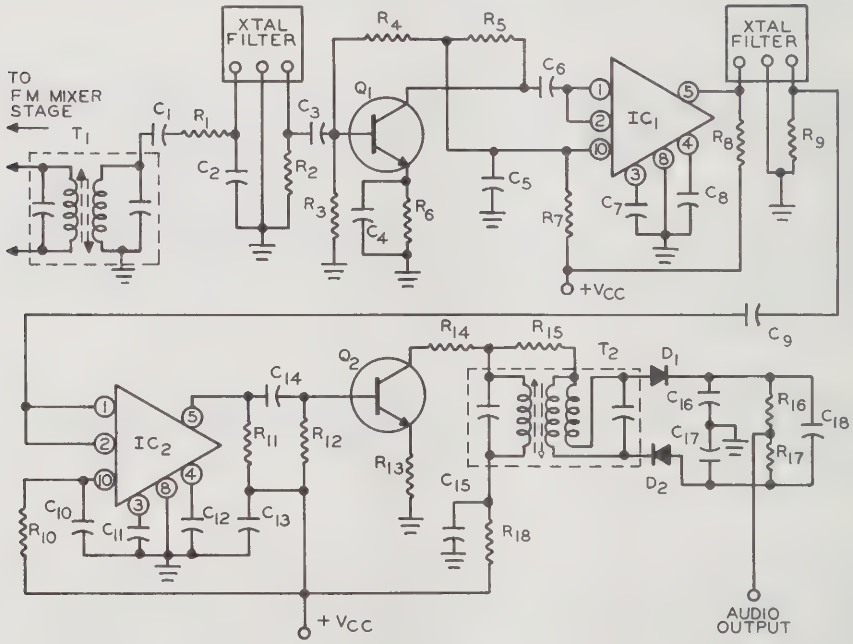


Figure 5

The input signal from the FM mixer stage is coupled through T_1 to the Crystal Filter. C_3 couples the output signal from the Crystal Filter to the base of Q_1. Following amplification by Q_1, C_6 couples the signal into IC_1. This integrated circuit consists of several differential amplifier stages as shown in Figure 6. From IC_1 the signal is passed through another Crystal Filter and applied to the input of IC_2. This integrated circuit is the same as IC_1 shown in Figure 6. The output signal from IC_2 is coupled to the base of Q_2 through C_{14}. T_2 couples the signal from the collector of Q_2 to the D_1, D_2 ratio detector. The audio output is taken at the junction of R_{16} and R_{17}.

Comparing the circuit of Figure 5 to that of Figure 4 shows that less stages are required with integrated circuits. However, usually more transistors are

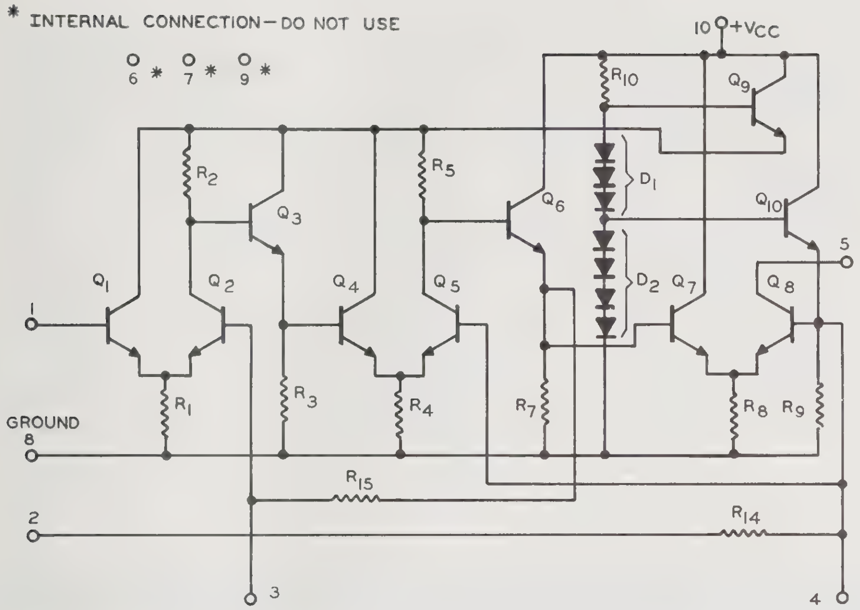


Figure 6

actually used when IC’s are employed. Note that there are 10 transistors in the circuit in Figure 6. Two of these IC’s are used in Figure 5; consequently, there are actually 22 transistors in the circuit of Figure 5 compared to four for Figure 4. In addition, the use of crystal filters can cut down the number of tuned circuits. In this circuit, only the mixer transformer T_1 and the ratio detector transformer T_2 require tuning. The crystal filters also provide the wide, uniform frequency response needed in the i-f amplifier for good FM stereo operation.

FM STEREO

Figure 7 shows a block diagram of the basic stereo FM transmission system. The left (L) and right (R) audio signals are applied to an Adder circuit which forms the L + R signal. This is basically a monaural signal which contains the signals from both channels. The right audio signal is also applied to an Inverter circuit which develops a −R signal. The L signal and the −R signal are then combined in another Adder which produces an L − R signal. This L − R signal is then used to modulate a 38-kHz subcarrier in a Balanced Modulator. The Balanced Modulator develops a set of L − R sidebands with the 38-kHz subcarrier suppressed. The 38-kHz subcarrier is obtained by doubling the frequency of a 19-kHz subcarrier. Because a reference is needed at the receiver to demodulate the 38-kHz double sideband suppressed carrier (DSSC) signal, a sample of the 19-kHz subcarrier is sent along as a **PILOT SIGNAL.**

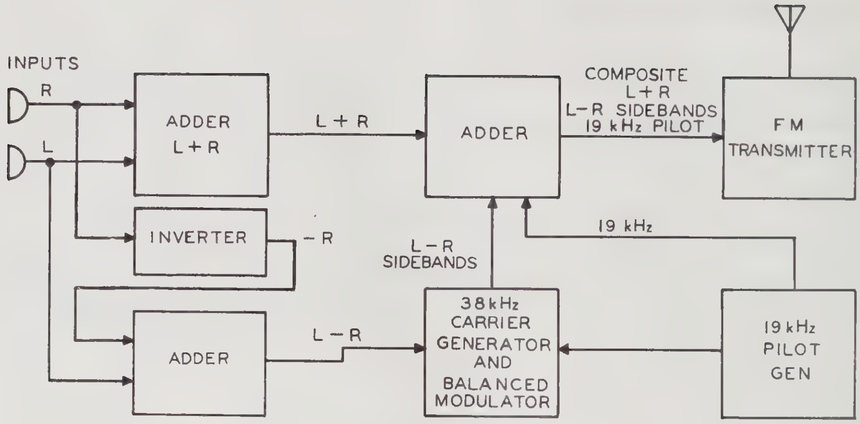


Figure 7

The L − R sidebands along with the 19-kHz pilot subcarrier are added to the L + R signal, and the entire composite signal modulates the FM transmitter carrier. Figure 8 shows the frequency distribution of the composite signal. When the FM signal is demodulated at the receiver, this is the signal that would appear at the output of the FM detector. The pilot subcarrier and L − R sidebands are above the audio range and would not be heard. With a conventional monaural FM receiver, only the L + R signal is heard, which appears as a normal monaural signal. To produce the two stereo signals, the L − R sidebands must be demodulated to develop the L − R signal. This signal is then combined with the L + R signal in a suitable matrix to produce the L and R stereo signals.

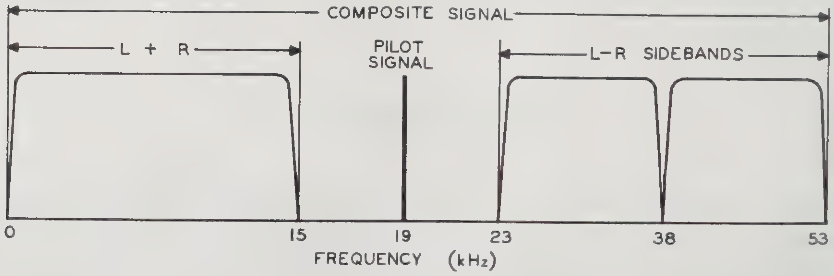


Figure 8

Figure 9 shows a block diagram of the basic stereo FM receiver demodulator circuit. The composite signal from the FM demodulator is first applied to a Filter. This separates the various parts of the composite signal. The 19-kHz pilot signal is used to synchronize a 38-kHz Carrier Generator. A Demodulator circuit recovers the original L − R audio signal by combining the L − R sidebands with the 38-kHz regenerated carrier. The L + R and L − R audio

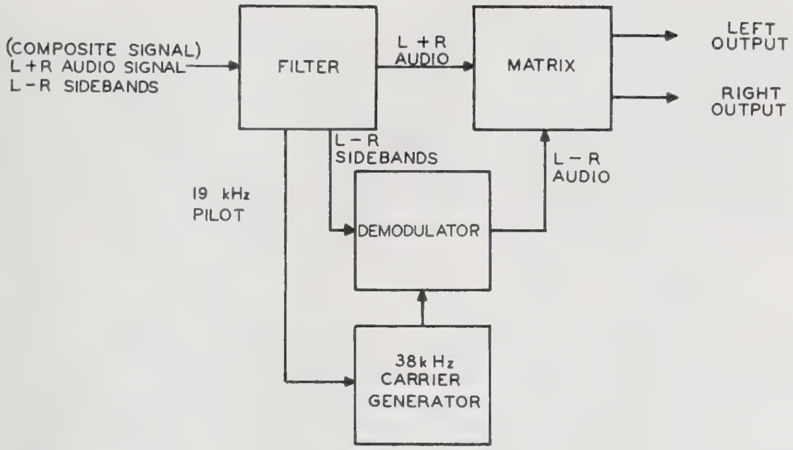


Figure 9

signals are then applied to a Matrix circuit which develops the separate left and right audio signals.

In addition to the stereo subcarrier, many FM stations transmit **SCA** subcarriers. These subcarriers carry "background music." A store or office "purchases" the service from an FM station, which installs a special receiver that demodulates only the SCA subcarriers. The SCA subcarriers are located between 53 kHz and 75 kHz. They must be filtered out to prevent interference with stereo FM reception.

Figure 10 shows the schematic diagram of a typical stereo demodulator circuit. The composite signal from the FM detector is applied through C_1 and the L_1C_2 filter to Q_1, the 19-kHz Amplifier. L_1 and C_2 are tuned to 53 kHz and filter out the lower portion of the SCA frequencies. L_3 and C_6 in the collector circuit of Q_1 are tuned to 19 kHz. C_7 couples the 19-kHz pilot signal from the collector of Q_1 to Q_2, the 38-kHz Doubler. The collector circuit of Q_2, consisting of C_8 and the primary of L_4, is tuned to 38 kHz. Thus, Q_2 operates as a frequency doubler. The L_4 secondary applies the 38-kHz signal as well as the L + R audio signal and the L − R sidebands to diodes D_2, D_3, D_4 and D_5 of the detector matrix circuit.

Since the emitter of Q_1 is not bypassed, the composite signal appears at the emitter. L_2 and C_3 are tuned to 75 kHz and remove the remaining upper SCA frequencies. R_{14} and C_{15} then couple the L + R audio signal along with the L − R sidebands to the detector matrix circuit.

There are several ways in which the demodulator/matrix circuit can be examined. The simplest way is to consider the demodulator/matrix circuit as

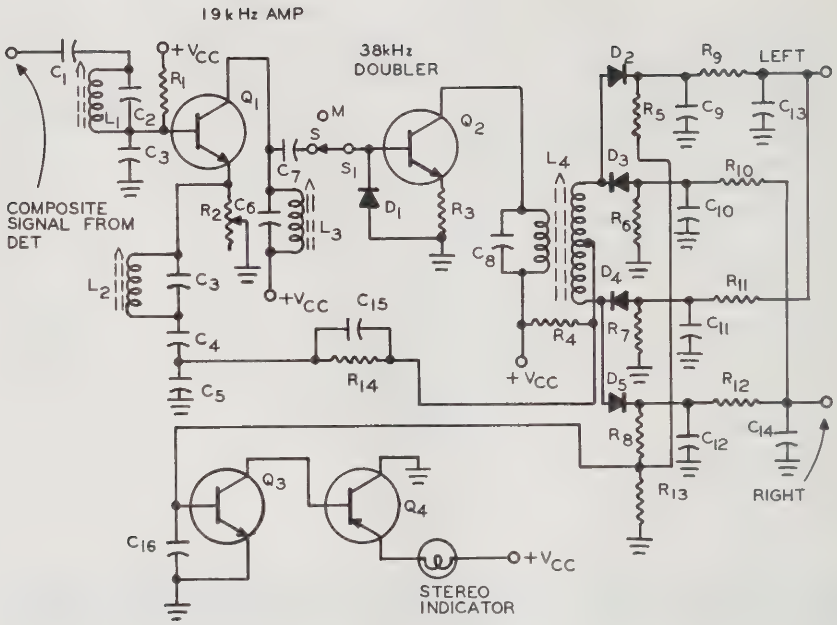


Figure 10

a switching circuit. If we were to observe the composite signal, L + R audio and L − R sidebands, applied to the center tap on the secondary of L_4, it would have the appearance shown in Figure 11A. When the 38-kHz signal of Figure 11B is added to the composite signal, the resultant signal shown in Figure 11C is obtained. This is the signal applied to the diode switching circuit. Careful examination of the waveform of Figure 11C shows that the left and right signals do not appear simultaneously but appear alternately in the waveform at a 38-kHz rate. To separate the two signals, the combined signal is applied to a switch operating at 38 kHz.

Diodes D_2, D_3, D_4 and D_5 form the 38-kHz switch in Figure 10. This circuit is redrawn in simplified form in Figure 12. With the diodes connected as shown, D_2 and D_4 conduct when the top end of the L_4 secondary is positive. D_3 and D_5 conduct when the top end of the L_4 secondary is negative. Figure

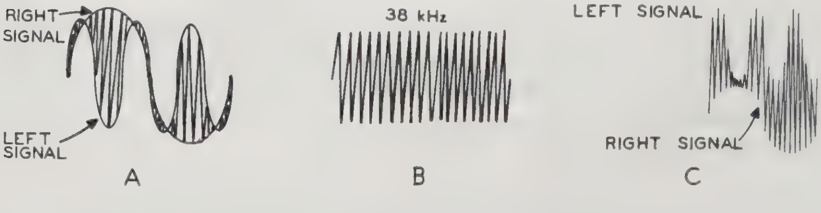


Figure 11

13 shows how the diodes conduct on the composite waveform of Figure 11C. The diodes thus switch the composite signal waveform between the left and right outputs. Capacitors C_9 to C_{12} filter out the 38-kHz pulsations in the left and right signals. R_9 to R_{12} along with C_{13} and C_{14} form a de-emphasis network to provide the proper frequency response from the FM signal. This is because FM stations use pre-emphasis. The diode switching circuit and its associated components form the demodulator and matrix circuits shown in the block diagram of Figure 9.

The circuit of Figure 10 will automatically switch from stereo to monaural operation. When a monaural signal is received, only L + R audio signals will be applied to Q_1. Thus, the Q_2 38-kHz doubler will be inoperative. R_{14} and C_{15} will apply only the L + R audio signals to the center tap of L_4. R_4, connected to the center tap of the L_4 secondary and $+V_{CC}$, forward biases D_2 and D_5, applying the L + R audio signals to both the left and right outputs for monaural operation. The forward bias provided by R_4 does not affect stereo operation.

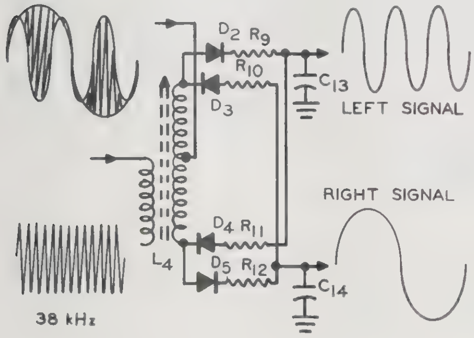


Figure 12

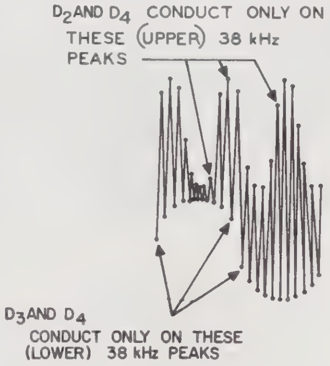

D2 AND D4 CONDUCT ONLY ON THESE (UPPER) 38 kHz PEAKS
D3 AND D4 CONDUCT ONLY ON THESE (LOWER) 38 kHz PEAKS

Figure 13

Q_3 and Q_4 form a stereo indicator circuit. When a stereo signal is being received, the 38-kHz signal develops a positive voltage across R_{13} and C_{16}. This signal forward biases Q_3 which, in turn, forward biases Q_4, lighting the stereo indicator. When a stereo signal is not present, the voltage appearing across R_{13} is not great enough to turn on Q_3 and the stereo indicator. The emitter resistor of Q_1 is made variable so the level of the 19-kHz signal applied to Q_2 and the resultant 38-kHz signal can be varied. R_2 is adjusted so that the stereo indicator lights when a station is transmitting a stereo broadcast.

Many modern stereo receivers use another type of multiplex decoder, called the "phase locked loop" decoder. This circuit is superior to that shown in Figure 10 in that stereo phase changes are automatically compensated for, and alignment is simplified. It also requires no 19-kHz trap.

Until development and refinement of the integrated circuit, the phase locked loop circuit was far too complex to be used in consumer multiplex decoders. Using a single IC and a small number of discrete components, a very simple phase locked loop decoder can now be constructed.

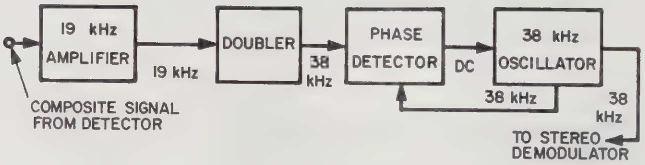


Figure 14

The basic phase locked loop system is shown in the block diagram of Figure 14. As in the conventional decoder circuit, the composite signal is fed from the FM detector to a 19-kHz amplifier, whose output is doubled in frequency by a doubler circuit. The 38-kHz doubler output signal goes to a phase detector, which compares the phase of the doubler output signal with that of the 38-kHz oscillator. The phase detector then produces a dc output that is proportional to the phase difference of the two 38-kHz inputs. This dc output voltage is used to correct the phase of the 38-kHz oscillator until it matches the phase of the doubler output. The circuit is called a phase locked loop because the phase of the oscillator output is synchronized with that of the transmitted subcarrier by a closed loop system.

Figure 15 is a diagram of a complete phase locked loop multiplex decoder. Virtually all of the circuitry is contained in one integrated circuit. The basic phase locked loop system occupies the top row of blocks. The three blocks

The Heathkit AJ-1510 digital tuner uses a phase locked loop multiplex decoder.

Courtesy Heath Co.

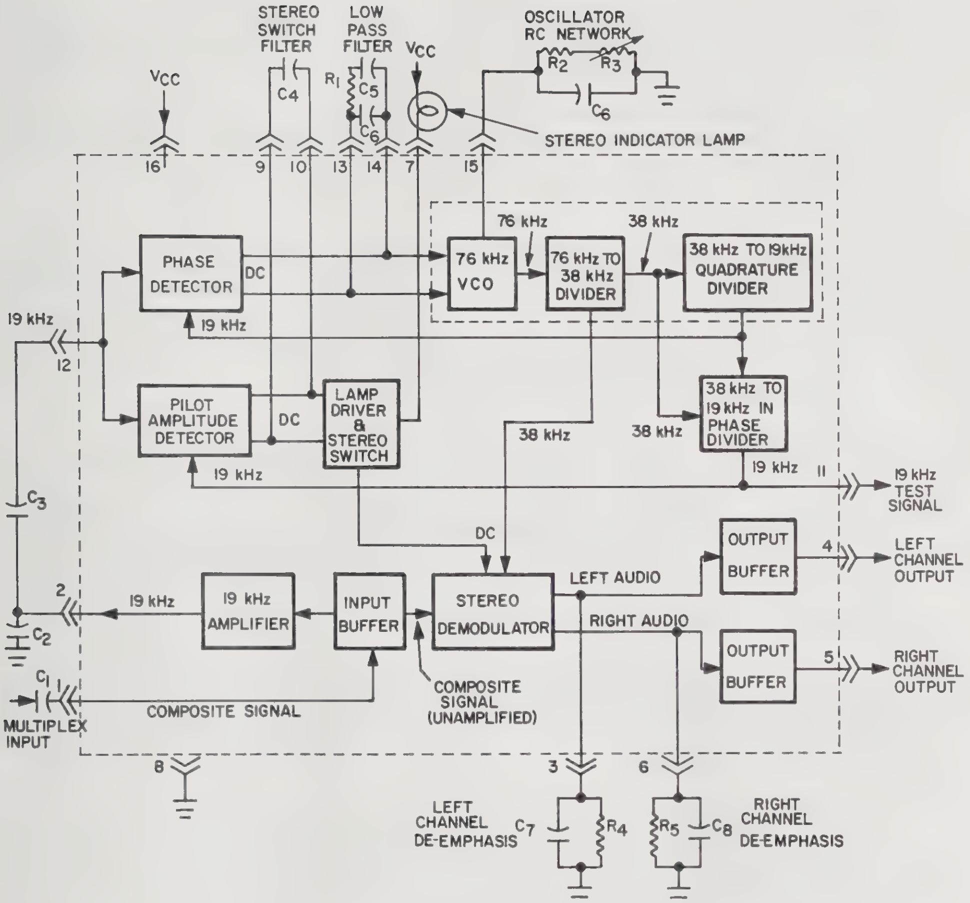


Figure 15

enclosed by dashed lines are together a sophisticated replacement for the 38-kHz oscillator block of Figure 14. In this case, however, the phase comparison frequency used is 19 kHz, and not 38 kHz.

Circuit tracing from the multiplex input, the composite signal is coupled from the FM detector to the input buffer through C_1 and pin 1 of the IC. The input buffer has two outputs, one of which feeds the 19-kHz amplifier. The second output connects to the stereo demodulator, and will be discussed later.

After the 19-kHz pilot signal has been amplified, it leaves the IC through pin 2 and is coupled through C_3 to pin 12 and back into the IC. C_2 is a bypass capacitor. Pin 12 connects to both the phase detector and pilot amplitude detector.

Also connecting to the phase detector block is the output of the 38 kHz to 19 kHz quadrature divider. As in the basic diagram of Figure 14, the two inputs are compared in phase, and a dc output, proportional to the phase difference, is produced. This dc correction voltage is amplified by a dc amplifier (within the 76-kHz VCO block) and used to vary the 76-kHz VCO frequency slightly, controlling the phase.

R_1, C_5 and C_6 form a Low-Pass Filter used to remove any remaining ac component from the phase detector output. Without this network, stereo separation may be degraded. R_2, R_3 and C_6 make up the VCO frequency control RC network. R_3 is the only alignment control in the decoder and is a coarse frequency adjustment for the VCO.

The 76-kHz VCO output signal goes to a two to one divider. One of the 38-kHz output signals of the divider feeds the 38 kHz to 19 kHz quadrature divider, where it is further divided to 19 kHz. Part of this stage's output is returned to the phase detector, with the remaining output feeding the 38 kHz to 19 kHz in-phase divider. A 38-kHz signal from the 76 kHz to 38 kHz divider is also fed into the 38 kHz to 19 kHz in-phase divider. The output of this stage is a 19-kHz signal that is in phase with the pilot signal and 90 degrees out-of-phase with the quadrature divider output. The 19-kHz output signal of the in-phase divider is fed to pin 11 as a test signal, as well as to the pilot amplitude detector.

The pilot amplitude detector receives the 19-kHz pilot signal and the 19-kHz output signal of the in-phase divider. When both signals are present, the pilot amplitude detector produces a dc output, which is filtered by stereo switch filter C_4 and applied to the lamp driver and stereo switch. As a result, when a stereo signal is received, the lamp driver and stereo switch are turned on, powering the stereo indicator lamp and stereo demodulator. If the received signal is mono, no dc will be applied to the lamp driver and stereo switch; the stereo indicator lamp and stereo demodulator will remain off.

The second output of the input buffer is connected to the stereo demodulator. The stereo demodulator recovers the original L − R audio signal by combining the L − R sidebands with the 38-kHz output of the 76 kHz to 38 kHz divider. The L + R and L − R signals are developed into the separate left and right audio signals.

The networks of C_7 and R_4, and R_5 and C_8 provide the necessary 75 µs de-emphasis, while the output buffers provide load isolation from the stereo demodulator. The phase locked loop feature of the demodulator causes the VCO output to be the same phase as the 38-kHz subcarrier oscillator at the FM transmitter. Therefore, the 38-kHz signal applied to the synchronous demodulator allows the left and right channel audio signals to be recovered with almost complete elimination of any 19 or 38-kHz components that might otherwise accompany the recovered audio.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

TUNER CIRCUITS

AM-FM I-F AMPLIFIERS

INTEGRATED CIRCUIT I-F AMPLIFIERS

FM STEREO

1. Most AM-FM/stereo receivers employ the same tuner circuit for both the AM and FM stations. True or False?

2. The same i-f stage can be designed to amplify both 455-kHz and 10.7-MHz i-f signals. True or False?

3. The agc bias employed on the Q_1 and Q_2 stages in Figure 2 is referred to as ____________ ________.

4. If the desired station frequency is 1000 kHz, to what frequency are T_1, C_{1A} and L_1, C_{1C} tuned (Figure 2)?

5. Why is the collector of Q_2 connected to a tap on the T_3 primary (Figure 2)?

6. What is an advantage of using a junction field effect transistor as an r-f amplifier?

7. How does D_1 in Figure 3 provide afc action?

8. Why is it possible to connect both the AM and the FM i-f transformers in series in Figure 4?

9. The element of Q_1 in Figure 4 that would have the highest voltage would be the (a) collector, (b) base, (c) emitter.

10. Explain the operation of the AM agc system in Figure 4 for a signal decrease.

11. During FM operation, Q_3 and Q_4 do not receive power from S_{1B}. True or False?

12. In Figure 4, D_5 and D_6 form a (a) gated beam detector, (b) ratio detector, (c) discriminator.

13. In Figure 4, the voltage at the junction of R_{24} and C_{21} is ____________ ____________(negative, positive, zero) when the receiver is properly tuned to the FM station.

14. In Figure 4, what would be the effect on receiver operation if the connection between R_{23} and S_{1C} were to open.

15. Give several advantages of using integrated circuits in FM i-f amplifiers.

SERVICING PROCEDURES

To efficiently service the large number of circuits in an AM-FM/STEREO tuner, the service technician must have a thorough understanding of the circuit operation. A logical troubleshooting procedure will quickly lead to the trouble. The logical troubleshooting procedure for an AM-FM/STEREO receiver is essentially the same as for conventional AM receivers. You would begin with a careful visual inspection of the unit. Unless the customer indicates that the unit blows fuses or otherwise overheats, apply power to the unit and observe its operation. Operate the unit in all modes to determine the general fault. Once you have determined the general fault (AM inoperative, FM stereo inoperative, etc.), you can use signal injection or signal tracing to locate the defective stage. After the defective stage is located, you can use voltage and resistance tests to locate the defective component.

To illustrate the servicing procedures for an AM-FM/STEREO tuner, assume that we are servicing the unit shown in Figure 16. This is a complete AM-FM/STEREO receiver, manufactured by the Admiral Corporation, and includes a stereo audio amplifier with phono and tape inputs. In our discussion, we will list the most common faults or symptoms and the procedure for isolating the defect.

Completely Inoperative Receiver

Unit Completely Inoperative, Pilot Lights Do Not Light—

> AC line circuit or power transformer defective—A check of the ac power circuit can be made by removing the line cord from the wall outlet and connecting an ohmmeter to the line cord. If the primary winding, line cord, switch, etc., are good, you should obtain a low resistance reading (25 ohms or less) when the power switch is turned on. If a proper reading is not obtained, you can use your ohmmeter to check the various parts of the circuit to locate the defect. Some units include a circuit breaker or fuse, and this should also be checked. If the fuse or circuit breaker is open, there may be a short or overload in the unit. If there are no visual signs of overload or a short, reset the breaker or replace the fuse. Observe the operation of the unit as you apply power. If the fuse or breaker holds, it was probably a line transient that caused the trouble. However, if the fuse or breaker opens again, there is a short or overload in the power supply or other sections of the circuit. You can use your ohmmeter to check the various power supply components to locate the defect.

Unit Completely Inoperative, Pilot Lights On—

> Power supply troubles or a trouble that affects both channels—Because the pilot lights are on, the T_{001} primary circuit must be all right. The

trouble must be in the power supply or something that affects both channels. You might make a quick signal injection test by touching the slider on the volume control for each channel, R_{007A} and R_{007B}. If an output is obtained, you can assume that the audio amplifiers and power supply are good and that the trouble is ahead of this point. You can apply test signals to the phono and tape inputs and determine if the trouble is ahead of the switch. The function switch in units like these has several decks and many contacts. Dirty and corroded contacts can render the switch inoperative. If the switch is in good condition and signals applied to the tape and phono inputs produce an output, the trouble is in the receiver. Signal injection or signal tracing can be used to locate the defective stage.

If the simple signal injection at the volume control produces no output, the trouble is in the amplifiers or power supply. A quick check of the power supply output voltage will show if the trouble is in the supply. If no output voltage is obtained, you can check the power transformer secondary voltage. The diodes and filter capacitors can be checked with an ohmmeter.

The power supply in this unit is somewhat nonconventional in that both the positive and the negative sides of the supply are above chassis ground. A floating ground system is employed. This is necessary since the circuit requires both positive and negative supply voltages. Figure 17 shows a simplified schematic of the power supply. In the circuit, as noted on the main schematic, all voltages are taken with respect to the floating ground, not the chassis ground. The power amplifier and preamplifier circuits operate from the 18.5-volt and 14.5-volt sources. The multiplex circuit operates from the 13-volt source. The AM-FM receiver circuit operates from the 8-volt source which is chassis ground. These voltages are all with respect to the floating ground.

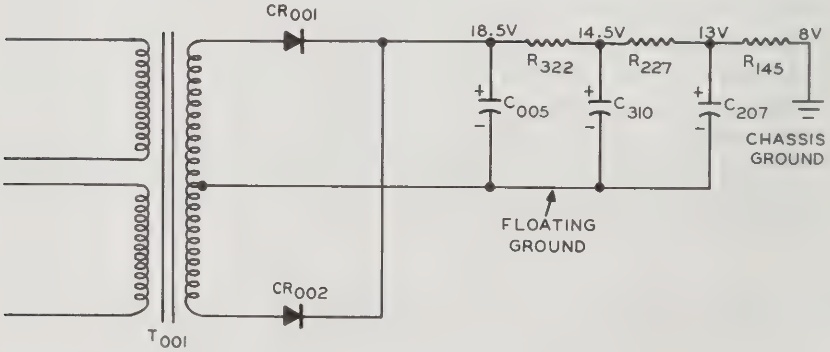
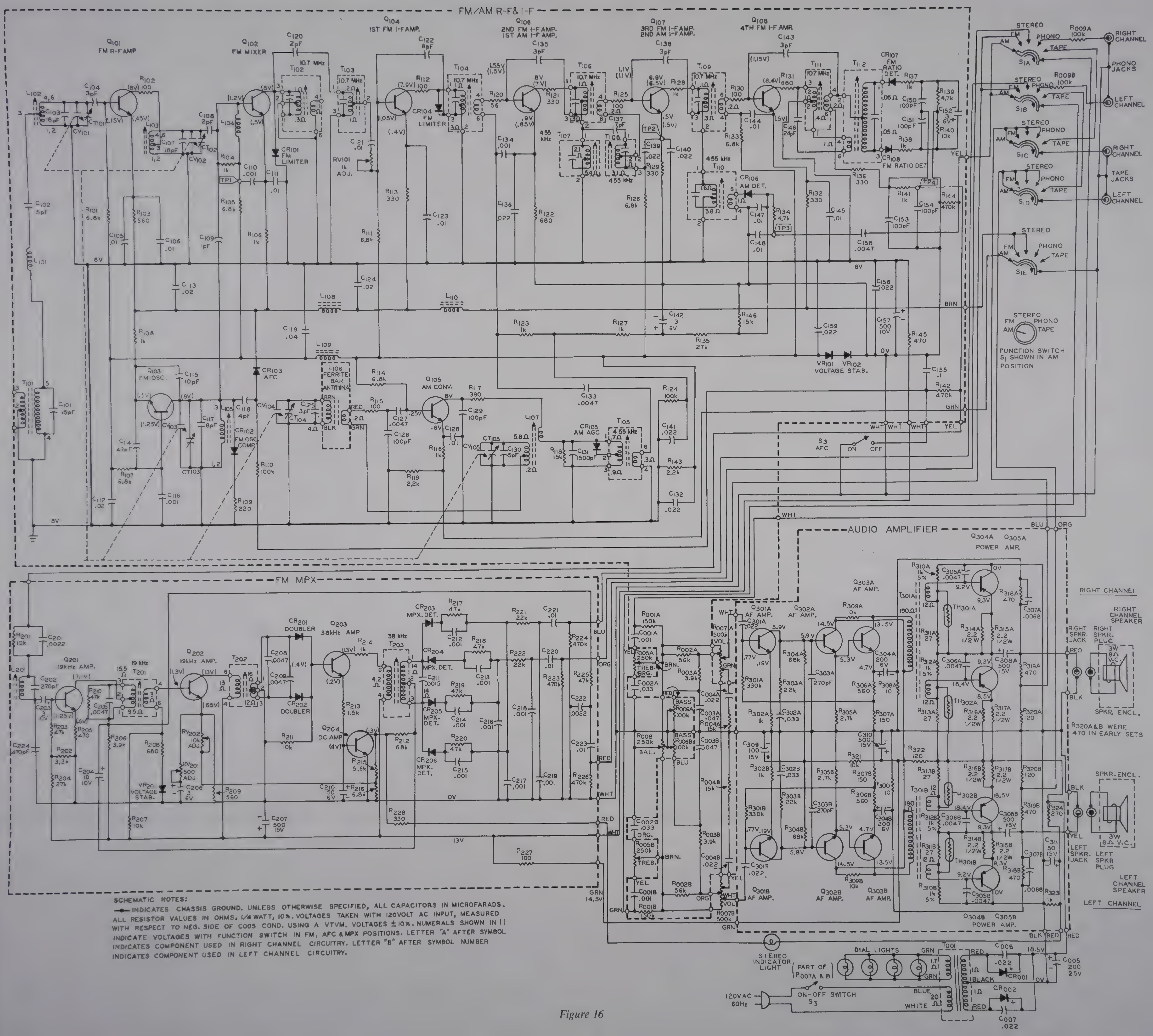


Figure 17



SCHEMATIC NOTES:
—•— INDICATES CHASSIS GROUND. UNLESS OTHERWISE SPECIFIED, ALL CAPACITORS IN MICROFARADS. ALL RESISTOR VALUES IN OHMS, 1/4 WATT, 10%. VOLTAGES TAKEN WITH 120VOLT AC INPUT, MEASURED WITH RESPECT TO NEG. SIDE OF C005 COND. USING A VTVM. VOLTAGES ±10%. NUMERALS SHOWN IN ( ) INDICATE VOLTAGES WITH FUNCTION SWITCH IN FM, AFC & MPX POSITIONS. LETTER "A" AFTER SYMBOL INDICATES COMPONENT USED IN RIGHT CHANNEL CIRCUITRY. LETTER "B" AFTER SYMBOL NUMBER INDICATES COMPONENT USED IN LEFT CHANNEL CIRCUITRY.

Figure 16

7550
20A

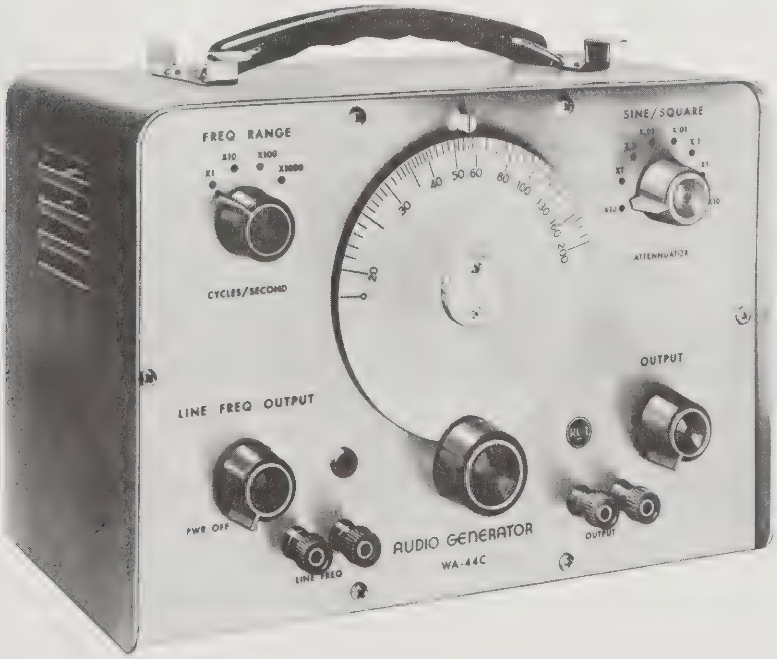
Always check the schematic notes when troubleshooting to see if a floating ground is used. Otherwise, your measurements may lead you to incorrent conclusions. It may help to draw a simplified schematic of the power supply as shown in Figure 17 to help in analyzing the circuit.

As mentioned before, a trouble in one channel might affect the operation of the entire unit. For example, a shorted driver transistor in one channel would cause excessive current in R_{322}, causing a reduction in the 14.5-volt supply. This would affect the operation of the driver stage in the other channel, along with the other circuits in the unit. It may be necessary to disconnect the various circuits in each channel from the power supply to isolate the trouble.

Amplifier Troubles

One Channel Inoperative On All Functions—

Defect in one of the amplifier channels or speaker system—With one channel functioning, you can conclude that the power supply is all right along with the operating channel. The speaker system can be quickly checked by interchanging the speakers. If the trouble remains in the



An audio oscillator, like the one shown above, can be used to provide test signal for troubleshooting audio circuits.
Courtesy RCA

same channel, the speakers are functioning properly. However, if the trouble switches channels, the speaker is defective. This can be verified with an ohmmeter check. Signal injection or signal tracing can be used to locate the output and work towards the input. The opposite procedure is followed when using signal tracing. Remember, with a stereo amplifier you have a built-in servicing aid, the operating channel. You can compare the operating channel to the inoperative channel to help locate the defect. Once the defective stage is located, voltage and resistance checks can be used to locate the defective component. Since the amplifier in the circuit of Figure 16 employs direct coupling, a defect in one stage can affect the others. Very careful voltage checks must be made to locate the trouble.

AM-FM Section Troubles

Both Channels Inoperative on AM and FM, Phono and Tape Inputs Normal—

Defect common to both the AM and FM receiver stations—Because the unit functions normally on the phono and tape inputs, the audio amplifier and power supply are operating. With both AM and FM inoperative, the trouble in a stage common to both functions (ahead of S_1). In the circuit of Figure 16 the only stages common to both functions are the Q_{106} and Q_{107} i-f amplifier stages. The best point to begin signal injection tests would be at the AM Detector, CR_{106}, and then work back towards the Q_{106} stage. Once you have isolated the defective stage, you can employ voltage and resistance tests to locate the defect.

A defect in the power supply could also make the AM and FM functions inoperative. A quick check of the power supply voltage would indicate if this is the problem. Remember, this unit has a floating ground. The chassis ground foils on the receiver circuit boards will be 8 volts positive with respect to the floating ground as shown in Figure 17. The function switch might also cause this trouble. This would be evident if a signal injected at the input and output of the AM detector produced no output.

AM Inoperative, FM Operates Normally—

The AM tuner is defective, defect in the AM i-f stages or detector—Since the FM section operates normally, the defect must lie in the circuits that are used only for AM operation. The possible stages would be the Q_{105} AM converter and CR_{106} AM detector stages. Because the FM section is operating normally, Q_{106} and Q_{107} must be operating. However, a defect in the AM i-f transformers T_{107}, T_{108} or T_{110} could cause the trouble.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

SERVICING PROCEDURES

COMPLETELY INOPERATIVE RECEIVER

AMPLIFIER TROUBLES

16. A conventional monaural FM receiver will develop a monaural signal output signal when tuned to a stereo station. True or False?

17. The L − R audio signal modulates the FM carrier in a stereo system. True or False?

18. In the stereo demodulator circuit, the 19-kHz pilot signal is combined with the L − R sidebands in the demodulator to develop the L − R audio signal. True or False?

19. What is the purpose of the matrix circuit in a stereo demodulator?

20. What is the purpose of L_1C_2 and L_2C_3 in the circuit of Figure 10?

21. Why does Q_2 in Figure 10 operate as a doubler?

22. Briefly explain the operation of the stereo demodulator in the circuit of Figure 10.

23. The circuit in Figure 10 will switch from stereo to monaural operation automatically. True or False?

24. In Figure 10, what effect would adjustment of L_4 have on circuit operation?

25. In Figure 14, the phase detector compares the amplitude of the doubler output with that of the 38-kHz oscillator. True or False?

26. In Figure 15, what is the source of the signal applied to the input buffer?

27. In Figure 15, what way would a short in C_7 affect operation of the decoder? (a) High-frequency noise would be heard in the left channel output. (b) There would be no audible change. (c) There will be no left channel output.

28. Suppose that CR_{001} is shorted in the circuit of Figure 16. What would be the effect and how would you check the diodes?

29. Suppose that C_{310} in Figure 16 shorts. What would be the symptom and how would you locate the trouble?

Signal injection or signal tracing can be used to locate the defect in the AM circuitry. With signal injection, start at the detector output (use an audio test signal at this point) and proceed through the i-f stages (455 kHz) to the converter (560-1600 kHz) stage. If you use signal tracing, start at the antenna and work toward the detector.

Although it is hard to say that one stage is more likely to be at fault than another, the converter stage is often the cause of trouble in the AM section. This stage operates both as a mixer and local oscillator. Changes in the characteristics of the transistor can result in failure of the local oscillator, although the stage may still function as a mixer. You can use a scope to check the operation of the oscillator. Make sure that the circuit oscillates when it is tuned from one end of the band to the other end.

FM Inoperative—Monaural and Stereo, AM Operates Normally—

FM tuner defective or a defect in the circuits peculiar to FM operation—Since the AM section operates normally, the circuits common to AM and FM operation, Q_{106} and Q_{107} stages, must be all right. As in servicing the AM section, signal tracing can be used to locate the defective stage.

When the function switch is in the FM position, the monaural FM signal is taken from the collector circuit of Q_{201} (junction of R_{206} and T_{201} primary). Signal injection (audio) can begin at this point and work backward toward the ratio detector through the Q_{201} stage. At the input to the detector, you must inject a 10.7-MHz modulated signal. Although an FM signal would be much better, an AM modulated 10.7-MHz test signal will usually work. Work back through the i-f amplifier stages. If you do not find the trouble in the i-f amplifiers, proceed to the front end. An 88 to 108-MHz test signal will be needed here. Once the defective stage is found, voltage and resistance tests can be used to locate the defective component.

The FM local oscillator stage may be hard to check. The frequency is too high to be observed on a normal service oscilloscope. Instead, the oscillator can be checked by measuring the bias. Any shift in bias voltage indicates that the local oscillator is not operating.

Stereo Troubles

FM Stereo Inoperative, Normal FM and AM Operation—

Defective stereo multiplex unit—First of all, make sure that the station tuned in is transmitting a stereo program. If the station is transmitting stereo and the stereo indicator light is on, the pilot carrier is being received and the 38-kHz subcarrier is being generated. If the phase of the stereo subcarrier is not correct, poor separation, distortion or unintelligible signals may result. If the adjustment is not too far off, T_{201} and T_{202} can be adjusted on a stereo program for maximum separation. Many FM stereo stations transmit announcements and news on one channel only. These programs can be used to align T_{201} and T_{202}. An objectionable swishing or sizzling sound may be present on some stereo signals. This is caused by interference from an SCA subcarrier. L_{201} is adjusted until this effect is minimized.

Correct alignment of the stereo multiplex system is best accomplished with a stereo signal generator. (It is important to note that stereo operation depends upon exact alignment of the i-f stages and detector. If the stereo multiplex circuit is correctly aligned and stereo reception cannot be obtained, you should check the i-f and detector alignment.) The alignment procedure differs from unit to unit. Consult the generator instruction manual and the receiver manufacturers' literature for the correct procedures.

The following alignment procedure is for the stereo multiplex circuit in Figure 16.

1. Connect the r-f output from the FM stereo generator to the antenna terminals.

2. Set the stereo generator for 9%, 19-kHz pilot signal with left channel modulation only.

This stereo Multiplex generator provides modulated r-f and composite signal outputs.

Courtesy Heath Co.

3. Set the receiver to the FM stereo mode, afc off. Connect a zero center VTVM to TP_4 and tune the stereo generator r-f frequency control for zero volts at TP_4. This assures that the stereo generator is properly set.

4. Connect a 68-kΩ resistor in series with the oscilloscope lead, and connect the scope to the collector of Q_{202}.

5. Peak T_{201} and T_{202} for maximum 19-kHz signal.

6. Move the scope lead with the 68-kΩ isolation resistor to the collector of Q_{203}. Adjust T_{203} for maximum 38-kHz signal. Due to the doubling action of CR_{201} and CR_{202}, the 38-kHz signal will have the waveshape shown in Figure 18.

7. Connect the scope lead to the left output on the multiplex board, C_{221}. Very slightly adjust T_{201} for maximum left channel audio. Check the right channel output of C_{220} which should be minimum. There should be at least a 10 to 1 ratio between the two signals (20 dB separation). You may have to readjust T_{201} slightly and go back and forth with the scope to obtain the best separation.

8. The FM stereo threshold adjustment is made by setting RV_{202} (in the Q_{202} emitter circuit) so the stereo indicator light is off when the receiver is off channel and connected to an antenna. RV_{201} is set to keep the indicator off when tuned to a monaural FM station.

9. As mentioned earlier, SCA trap L_{201} is adjusted for a minimum swishing or sizzling sound when the receiver is tuned to a stereo station with an SCA subcarrier.

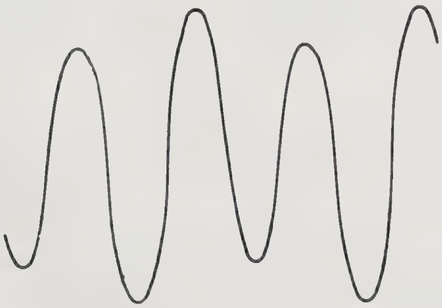


Figure 18

Signal tracing is about the best method to use when troubleshooting an FM multiplex unit. Most multiplex generators provide a composite output as well as an r-f output. Thus, you can apply the stereo r-f signal to the antenna terminals or the composite signal to the input of the multiplex unit, C_{201} R_{201}

in the circuit of Figure 16. The r-f signal has the advantage in that the i-f response is also checked.

Most stereo generators have provisions to modulate one channel at a time, left or right. Signal tracing is easier if only one channel is modulated. Figure 19 shows how the opposite signal should appear with modulation on only one channel. In Figure 16 this signal appears at Q_{201}, the junction of T_{201} and R_{206} and is applied through C_{204} to the center tap of T_{203}. T_{201} provides a tuned circuit to remove the 19-kHz pilot signal from the composite and apply it to Q_{202}. A scope can be used to check the output of T_{201} and the operation of the Q_{202} stage. CR_{201} and CR_{202} form a full-wave rectifier which doubles the 19-kHz pilot signal and applies to Q_{203} to form the 38-kHz subcarrier signal. T_{203} supplies a push-pull 38-kHz driving signal to the demodulator. A defect in the Q_{202} and Q_{203} stages would remove the 38-kHz signal and prevent stereo operation. With only one channel modulated, there should be maximum output on the active channel and minimum output on the inactive channel. If adjustment of T_{201} and T_{202} will not obtain this, check the components in the demodulator, primarily CR_{203} to CR_{206}. An ohmmeter can be used to check the diodes. Make sure that the forward resistance of the four multiplex detector diodes are matched.

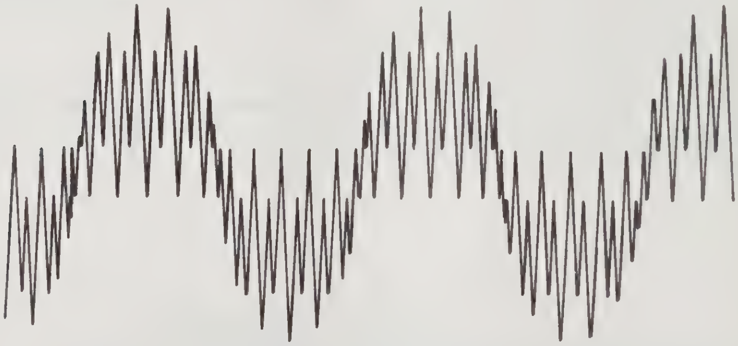


Figure 19

If a stereo generator is not available, an audio oscillator can be used to supply a 19-kHz test signal. It is important, however, that the audio generator be accurate. This will allow you to check out the Q_{201}, Q_{202} and Q_{203} stages. As mentioned earlier, a stereo program with an announcement on one channel can be used to set the separation.

In general, stereo reception requires a higher signal level than monaural for good reception. Often an outside antenna is required for good stereo reception. Many modern TV antennas have provisions for FM reception, and a line splitter made for the purpose can be used to feed both the TV receiver and the AM-FM/STEREO receiver.

The following Practice Exercise questions cover the subjects which you have just studied. They are:

SERVICING PROCEDURES

AM-FM SECTION TROUBLES

STEREO TROUBLES

30. Suppose that C_{301A} in the right channel of Figure 16 is open. Describe the effect and how you would locate the trouble.

31. Suppose that Q_{303B} in the circuit of Figure 16 has an open in the base connection. What effect would this have on circuit voltages?

32. If the primary of T_{104} in Figure 16 opens, (a) only AM reception will be affected, (b) only FM reception will be affected, (c) both AM and FM reception will be affected.

33. What would be the effect if C_{157} shorts in Figure 16?

34. Assume that the capacitor resonating T_{108} in Figure 16 has shorted. What is the effect? Describe how you would isolate the trouble.

35. If C_{133} in Figure 16 opens, (a) only FM reception will be affected, (b) only AM reception will be affected, (c) both AM and FM reception will be affected.

36. Suppose that the secondary of T_{201} in Figure 16 is open. Would this affect monaural FM reception?

37. Suppose that L_{102} in the circuit of Figure 16 is open. What would be the effect?

38. Suppose that the stereo signal is distorted. What adjustments would you make in the circuit of Figure 16 to eliminate the distortion?

39. A swishing or sizzling sound on a stereo program is caused by a misadjustment in the circuit of Figure 16 or (a) T_{202}, (b) T_{203}, (c) L_{201}.

40. **What would be the effect if CR_{201} opens in the circuit of Figure 16?**

41. **If Q_{202} develops a base-to-emitter short in the circuit of Figure 16 (a) the composite signal will not be applied to T_{203}, (b) the 38-kHz subcarrier will not be generated, (c) the stereo indicator will light on only monaural stations.**

SUMMARY

Most hi-fi stereo systems include an AM-FM/STEREO receiver. At first glance this can appear to be quite a complex unit. However, if the unit is broken down into its basic sections, the circuits are quite simple. The servicing procedures are the same as for a conventional AM or FM receiver. Start by isolating the trouble to a particular section of the unit and then to a particular stage. This can be accomplished by using signal tracing or signal injection techniques. Once the defective stage is located, voltage and resistance tests can be made to locate the defective component.

A stereo FM generator is very helpful in aligning and troubleshooting the stereo multiplex circuit. An audio generator and on-the-air programs can be used if a stereo generator is not available.

IMPORTANT DEFINITIONS

CROSS MODULATION—Modulation of a desired carrier by a stronger interfering signal.

FRONT END—The name generally given to the section of a receiver consisting of the r-f amplifier, mixer and local oscillator stages.

PILOT SIGNAL—A 19-kHz signal sent along with the FM stereo multiplex signal to serve as a reference for generating the 38-kHz subcarrier.

REVERSE AGC—The arrangement where a reverse-bias voltage is applied to a stage to reduce emitter current and, in turn, reduce the stage gain.

SCA—Subsidiary Communications Authorization—The SCA allows FM broadcast stations to transmit subcarriers containing special program material such as background music, special announcements, etc.

PRACTICE EXERCISE SOLUTIONS

1. False—Due to the differences in frequency, separate tuner circuits are generally employed for the AM and FM frequencies.

2. True—By using a double i-f transformer arrangement, both the 455-kHz AM and 10.7-MHz FM i-f signals can be handled in the same stage.

3. reverse agc

4. C_{1A} and T_1 are tuned to the incoming signal frequency (1000 kHz), and C_{1C} and L_1 are tuned 455 kHz above the incoming signal frequency (1000 kHz + 455 kHz = 1455 kHz).

5. Collector Q_2 as well as those of the other transistors in the tuner are "tapped down" on the collector tank circuit to provide the proper impedance match as well as provide high circuit Q.

6. The reverse-biased input circuit of the junction field effect transistor provides a high input impedance and reduces the possibility of cross modulation.

7. D_1 is a voltage variable capacitance diode. As the afc voltage increases the reverse bias, the capacitance of D_1 decreases, causing an increase in frequency and vice versa.

8. Due to the manner in which they are connected and the frequencies involved, only one transformer "appears" in the circuit for a given signal frequency.

9. (c) emitter.—The emitter is connected to the supply, whereas the collector is grounded.

10. A decrease in signal level decreases the negative agc voltage applied to the base of Q_1. This causes an increase in forward bias on Q_1, increasing emitter current and circuit gain. An increase in Q_1 emitter current reduces the negative voltage at the Q_1 emitter. This reduced negative voltage applied as an agc voltage to the AM tuner increases the gain of the r-f amplifier and mixer circuits.

11. False—During AM operation, the Q_3 and Q_4 stages do not receive power.

12. (b) ratio detector.

13. zero

14. The receiver would operate normally except that no afc action would be provided. As a result, the receiver could drift off frequency and require frequent retuning.

PRACTICE EXERCISE SOLUTIONS (Continued)

15. Integrated circuits provide high gain in a single package and built-in limiting. The wiring is simpler.

16. True—The conventional monaural FM receiver responds to the L + R signal which is basically a monaural signal.

17. False—The L − R audio signal modulates a 38-kHz subcarrier producing a DSSC signal. The L − R sidebands modulate the FM carrier.

18. False—The 19-kHz pilot signal is used to develop the 38-kHz subcarrier which is combined with the L − R sidebands to produce the L − R audio signal.

19. The matrix circuit combines the L + R and L − R audio signals to form the L and R stereo signals.

20. The circuits consisting of L_1, C_2 and L_2, C_3 filter out the SCA frequencies.

21. Doubler operation in the Q_2 stage is obtained by tuning the collector circuit of Q_2 to twice the input signal frequency, 2 × 19 kHz or 38 kHz.

22. L_4 combines the L + R audio, L − R sidebands and 38-kHz signals. The result is a signal that contains the left and right audio signals appearing alternately at a 38-kHz rate. The diode demodulator switches the composite signal between the left and right outputs at a 38-kHz rate to separate the two signals.

23. True—The demodulator circuit will switch automatically from stereo to monaural operation.

24. L_4 would control the "phase" of the signal applied to the diode switching circuit. The phase of the 38-kHz signal must be correct or the demodulator will not operate properly.

25. False—Phase is compared, not amplitude.

26. The FM second detector is coupled to the buffer input.

27. (c) There would be no left channel output. The left channel would be directly connected to ground.

28. With CR_{001} shorted, the power transformer secondary would be shorted every time CR_{002} conducts. This would cause CR_{002} as well as T_{001} to overheat. If the unit contained a fuse or circuit breaker, it would open. The unit would be completely dead, but the pilot lights would probably light. The diodes can be checked with an ohmmeter. The resistance should be

PRACTICE EXERCISE SOLUTIONS (Continued)

high in one direction and low when the meter leads are reversed across each diode.

29. With C_{310} shorted, the unit would appear completely dead, as no voltage would reach the audio driver stage and all stages preceding that point. A signal injection test at the volume control would produce no output. R_{322} may burn up. Proceeding with the signal injection tests toward the power amplifier would show that only the power output stage is operating. Voltage measurements in the driver stage would show the lack of supply voltage. Tracing the voltage back to the power supply would show zero volts following the 18.5-volt point. An ohmmeter check would show that C_{310} is shorted.

30. With C_{301A} open, the right channel would be inoperative on all functions. Switching the speakers would show that the trouble is not in the speakers. Signal injection at the volume control would produce no output. However, when the test signal is fed to the base of Q_{301A}, an output would then be obtained. Bridging C_{301A} with another capacitor would produce an output.

31. An open in the base lead of Q_{303B} would cut off Q_{303B}. This would reduce its collector current to its low cutoff value, raising collector voltage and decreasing the emitter voltage. Due to the feedback from the emitter of Q_{303B} to Q_{301B}, all the voltages in the Q_{301B} and Q_{302B} stages would be affected.

32. (b) only FM reception will be affected.—If the primary of T_{104} opens, the first FM i-f stage will be inoperative. As the result, the FM section will be inoperative. However, the AM section will operate normally.

33. If C_{157} shorts, the supply voltage to the AM and FM receiver circuits will be reduced to zero, making them inoperative.

34. With the capacitor across T_{108} shorted, the AM section would be inoperative. The Q_{107} stage would amplify the 10.7-MHz FM i-f signals but not the 455-kHz AM i-f signals. Isolation of the trouble could begin at the AM detector. An output would be obtained with an i-f signal injected either at the detector or at the base of Q_{107}. However, when the test signal is moved to the Q_{106} stage, no output would be obtained. Since the i-f amplifier operates normally on the 10.7-MHz FM i-f signal, the T_{107}-T_{108} i-f transformer assembly would be suspected. Due to the low resistance of the windings, resistance readings must be made carefully to determine the trouble.

35. (b) only AM reception will be affected.—C_{133} couples only the AM signal from the Q_{105} converter stage to the base of Q_{106}.

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EXAMINATION CHECK SHEET

1. A - THE AGC VOLTAGE IN THE CIRCUIT OF FIGURE 2 -- BECOMES MORE NEGATIVE AS THE SIGNAL LEVEL INCREASES.
This circuit employs reverse agc. Since NPN transistors are employed, making the bases more negative reduces emitter current and stage gain.

2. D - THE ADVANTAGE OF USING AN FET IN THE R-F AMPLIFIER OF FIGURE 3 IS -- REDUCED CROSS MODULATION.
The gate input circuit of the FET is reverse biased to provide a high input impedance and reduced cross modulation.

3. A - WITH REGARD TO THE AFC ARRANGEMENT IN FIGURE 3, MAKING THE -- CATHODE OF D_1 MORE NEGATIVE DECREASES FREQUENCY.
Making the cathode of D_1 more negative decreases the reverse bias on D_1. As a result, the effective capacitance increases, causing a decrease in frequency.

4. B - IN THE CIRCUIT OF FIGURE 4 -- Q_1 AND Q_2 AMPLIFY BOTH 10.7-MHz AND 455-kHz I-F SIGNALS.
Q_1 and Q_2 handle both i-f signal frequencies, whereas Q_3 and Q_4 handle only the 10.7-MHz i-f signals.

5. A - WITH RESPECT TO THE CIRCUIT OF FIGURE 5 -- THE BANDPASS IS SET BY THE CRYSTAL FILTER.
The crystal filters set up the desired bandpass and do not amplify the i-f signal. Diodes D_1 and D_2 form a ratio detector.

6. B - IN A STEREO DEMODULATOR CIRCUIT, THE 19-kHz PILOT SIGNAL IS -- USED TO GENERATE THE 38-kHz SUBCARRIER.
The pilot signal supplies the correct phase and frequency for the 38-kHz subcarrier signal.

7. D - REFERRING TO THE CIRCUIT OF FIGURE 10 -- L_4 AND C_8 ARE TUNED TO 38 kHz.
Q_2 operates as a doubler stage and L_4 is tuned to twice the 19-kHz pilot input signal, or 38 kHz.

8. D - SUPPOSE CR_{001} IN THE CIRCUIT OF FIGURE 16 OPENS. WHAT WILL BE THE EFFECT? -- 60-Hz HUM.
With CR_{001} open, the power supply becomes a half-wave rectifier. The output voltage will reduce, causing reduced output, distortion and 60-Hz hum.

9. A - IF R_2 IN FIGURE 15 IS OPEN, WHAT WILL BE THE RESULT? -- THE 76-kHz VCO WILL NOT OSCILLATE.
With R_2 open, the frequency determining network is not a complete circuit.

10. D - WHAT WILL BE THE EFFECT IF C_{211} IN THE CIRCUIT OF FIGURE 16 OPENS? -- DISTORTED OR NO STEREO OUTPUT.
With C_{211} open, the secondary of T_{203} will not resonate at 38-kHz and demodulation will not occur.

PRACTICE EXERCISE SOLUTIONS (Continued)

36. No—However, stereo reception would not be possible since the secondary of T_{201} supplies the 19-kHz pilot signal to the 38-kHz subcarrier stage.

37. With L_{102} open, the FM r-f amplifier would not have a tuned input circuit. Under these conditions, the sensitivity and selectivity of the front end would be reduced. Reception of strong signals would still be possible.

38. Distortion is generally a result of incorrect 38-kHz subcarrier phase. This can be corrected by adjusting T_{201} and T_{202}.

39. (c) L_{201}.—The sizzling or swishing sound is generally caused by interference from an SCA subcarrier. L_{201} forms a trap circuit to remove the SCA subcarrier.

40. If CR_{201} opens, Q_{203} will only receive a 19-kHz pulsating signal.

41. (b) the 38-kHz subcarrier will not be generated.

QUESTIONS

IMPORTANT—These instructions **MUST** be accurately followed to avoid loss, or errors in grading.

Indicate your answer on this sheet by filling in the box for the most correct answer to each question, as illustrated in the example below.

When all questions have been answered, place the answer card in the proper position to line up the boxes on the card with the boxes on the sheet.

Next, copy the complete lesson code into the space provided on the card, and fill in the answer boxes to correspond with those previously filled in on this sheet.

Before mailing, be certain your correct student number, name and address appear on the card.

LESSON CODE
7550A

Example:

A ☐ B ☐ C ■ D ☐ Egg yolks are found in
(A) watermelon. (B) tomatoes. (C) eggs. (D) dill pickles.

1. A ☒ B ☐ C ☐ D ☐ **The agc voltage in the circuit of Figure 2**
(A) becomes more negative as the signal level increases. (B) becomes more positive as the signal level decreases. (C) becomes more positive as the signal level increases. (D) is fixed.

2. A ☐ B ☐ C ☐ D ☒ **The advantage of using an FET in the r-f amplifier of Figure 3 is**
(A) low input impedance. (B) increased cross modulation. (C) lower circuit Q due to increased loading. (D) reduced cross modulation.

3. A ☒ B ☐ C ☐ D ☐ **With regard to the afc arrangement in Figure 3, making the**
(A) cathode of D_1 more negative decreases frequency. (B) cathode of D_1 less negative decreases frequency. (C) cathode of D_1 more negative decreases effective capacitance. (D) cathode of D_1 less positive decreases effective capacitance.

4. A ☐ B ☒ C ☐ D ☐ **In the circuit of Figure 4**
(A) Q_1 amplifies only the 10.7-MHz i-f signal. (B) Q_1 and Q_2 amplify both 10.7-MHz and 455-kHz i-f signals. (C) Q_3 amplifies only 455-kHz i-f signals. (D) D_5 and D_6 form a discriminator.

5. A ☒ B ☐ C ☐ D ☐ **With respect to the circuit of Figure 5**
(A) the bandpass is set by the crystal filter. (B) the crystal filters amplify the i-f signal. (C) an external detector is required. (D) Q_2 operates as a detector.

6. A ☐ B ☒ C ☐ D ☐ **In a stereo demodulator circuit, the 19-kHz pilot signal is**
(A) added to the L + R audio signal. (B) used to generate the 38-kHz subcarrier. (C) combined with the L − R carrier signal. (D) applied to the demodulator.

7. A ☐ B ☐ C ☐ D ☒ **Referring to the circuit of Figure 10**
(A) L_1 and C_2 are tuned to 19 kHz. (B) L_2 and C_3 are tuned to 38 kHz. (C) L_3 and C_6 are tuned to 38 kHz. (D) L_4 and C_8 are tuned to 38 kHz.

8. A ☐ B ☐ C ☐ D ☒ **Suppose that CR_{001} in the circuit of Figure 16 opens. What will be the effect?**
(A) Reduced audio output and 120-Hz hum. (B) Distortion of the AM signal only. (C) Overheating of the power amplifier transistors. (D) 60-Hz hum.

9. A ☒ B ☐ C ☐ D ☐ **If R_2 in Figure 15 is open, what will be the result?**
(A) The 76-kHz VCO will not oscillate. (B) The 76-kHz VCO will operate at 38 kHz. (C) The phase detector will have an ac output. (D) The 19-kHz amplifier will cross modulate.

10. A ☐ B ☒ C ☐ D ☐ **What will be the effect if C_{211} in the circuit of Figure 16 opens?**
(A) SCA interference. (B) Increased separation. (C) A distorted monaural FM output. (D) Distorted or no stereo output.

UE75A

UNIT EXAMINATION FOR
COURSE 75

This examination contains a number of different type questions: multiple choice, true or false, fill in the blank and direct question. To assist us in grading, please print your answers clearly on the answer sheet. **COMPLETE THE PORTION STATING YOUR NAME, ADDRESS AND STUDENT NUMBER ON THE ANSWER SHEET AND SEND ONLY THE ANSWER SHEET FOR GRADING.** Retain the examination questions for your records.

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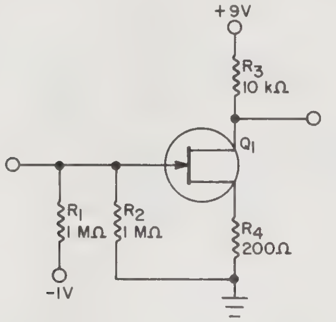
1. Suppose that a VOM with a sensitivity of 1000 ohms per volt is used to measure the voltage drop across R_2 in the circuit shown below. The meter is set on the 1-volt range. Can an accurate measurement be made? [illegible]



2. An emission-type tube tester measures the transconductance of the tube under test. True or [✓ False]?

3. A digital multimeter usually uses a meter movement on its low current range. True or [✓ False]?

4. An r-f signal generator should extend from a low frequency of 250 kHz to be used in servicing automobile radios.

5. The most important quality test for transistors is to determine BETA.

6. Signal injection is usually performed with what type of test equipment? signal generator

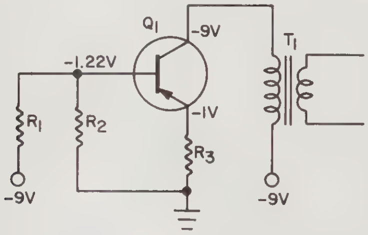
7. Signal tracers are of two basic designs. What are they? audio amplifier [illegible]
tuned [illegible] freq. radio [illegible]

8. What is the typical level of oscillator output voltage in a transistorized portable AM radio? .1 Volt

9. If the collector of the first i-f amplifier in a transistorized receiver were open, would a noticeable decline in total circuit current occur? yes

10. When only one stage of an integrated circuit becomes faulty, what service action would you take? substitute a good one

11. In the circuit shown below, suppose that the connection between the base of Q_1 and the junction of R_1 and R_2 opens. Will this cause the emitter voltage of Q_1 to increase or decrease? decrease



12. In the circuit of Question 11, what change would occur in the collector voltage under the given conditions? none

13. What is a good test point to use in a radio receiver for a signal injection test to split the receiver into two parts, isolating the trouble to the r-f or audio-frequency sections? volume control

14. Refer to the schematic diagram of the AM broadcast superheterodyne radio receiver included at the back of this exam. If you are aligning this receiver, would you adjust the slug in coil L_2, the oscillator coil, to provide tracking at the high or the low end of the broadcast band? low

15. Refer to the diagram for the receiver at the back of this exam. Suppose that you are employing signal injection to locate the faulty stage in this receiver. To what frequency would you tune an r-f generator to test the Q_2 and Q_3 stages? 455 k

16. Refer to the schematic diagram of the receiver at the end of this exam. Suppose that Q_5 develops a base-to-emitter short. Would this cause the emitter voltage of Q_6 to increase or decrease? ______________

17. Suppose that an automobile receiver employs NPN transistors and is arranged for a positive ground system. Would the collectors of the transistors be connected to the negative supply or would they be grounded? grounded

18. Most automobile radios use permeability tuning for high electrical stability. [✓ True] or False?

19. The most common i-f frequency used in FM automobile receivers is 10.7 MHz

20. If an automobile tape player is producing rough, low-level sound, what two measures should you take first?
[illegible]

21. What is the name of the intercom system in which each station can call any other station in the system? all master

22. In many master/slave intercom systems, what serves as a microphone in the slave units? speaker

23. What provides the unit-to-unit connection of a wireless intercom system? AC line

24. The constant voltage output of a public address amplifier permits the use of matching transformers to fulfill the power requirements of the various speakers of a sound system. [✓ True] or False?

25. Besides the power amplifier, what are the two most common elements of a public address system? microphone + speaker

26. All hi-fi amplifier specifications generally state the output power rating in one form or another. [✓ True] or False?

27. Tuners are usually rated in terms of at least one basic specification. What is it? The sensitivity

28. Trouble occurring in a stereo amplifier always affects both output channels equally. True or [✓ False]?

29. Can the troubleshooting technique of isolation be used in analyzing problems with the input devices of a stereo system? yes

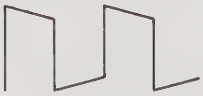
30. What is the recommended minimum load impedance of most home entertainment hi-fi stereo systems? 4Ω

31. If touching the ungrounded terminal of the volume control with a screwdriver causes a noise at the speaker of a portable record player that was reported to have no output, this indicates that the problem is in the amplifier. True or [✓ False]?

32. Are direct-coupled audio amplifiers more likely to have failures of input transistors or output transistors? output

33. In a stereo amplifier, if you think that a particular stage in one channel contains a malfunction, what simple examination can be made?
compare voltage measurement [illegible]

34. Suppose that you are applying a 1-kHz square wave test signal to a high-fidelity amplifier. If you obtain the output waveshape shown below, would you suspect poor high- or poor low-frequency response?
poor low-freq



35. If both channels of a stereo amplifier are faulty, examination of the unit most likely would begin with what section? power

36. Which does slippage in the drive system of a record changer generally cause, rumble or wow? wow

37. Most low cost record changers use pulley motors.

38. A stylus pressure gauge is not needed when a pickup arm is dynamically balanced. True or [✓ False]?

39. A Strobe disc is useful in determining turntable speed.

40. The two types of tracking angle error are lateral and [illegible].

41. Compared to a ceramic cartridge, the output of a magnetic cartridge is less.

42. If the bias signal source in a tape recorder is defective, what effect will be noted during playback of previously recorded tape? none

43. Good high-frequency response for tape recorders requires what head gap size as a maximum? .25 mil

44. Cassettes and cartridges are different names for the same type of tape container. True or [✓ False]?

45. Erasure of a magnetic tape requires exposing the tape to a strong magnetic field. [✓ True] or False?

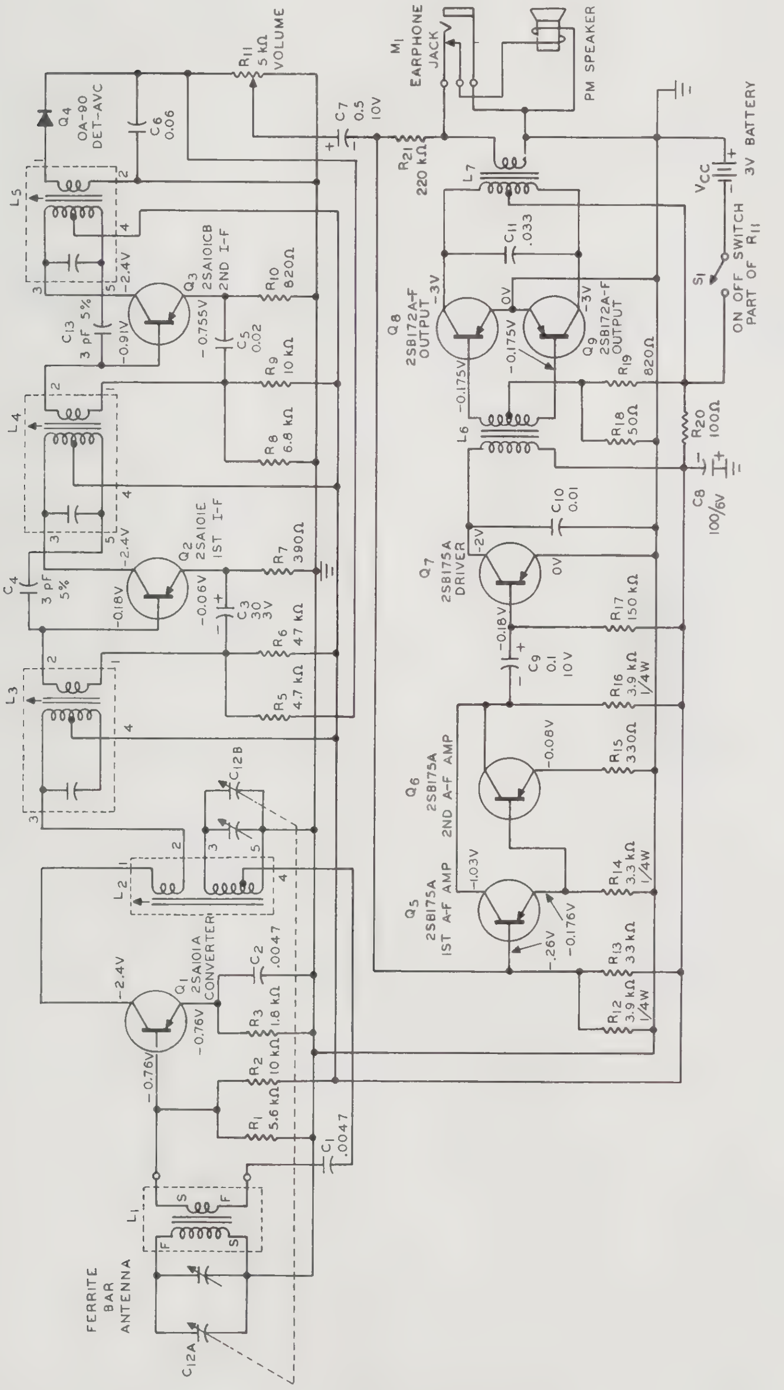
46. When a strong signal modulates a weaker signal in a receiver's front end, the result is called cross modulation.

47. In many FM i-f circuits, crystal or ceramic filters replace LC circuits.

48. What is the frequency of the pilot signal in an FM/stereo multiplex system? 19 KHz.

49. All phase-locked loop decoders require a 19-kHz trap. True or [✓ False]?

50. In many FM/stereo receivers, the 38-kHz subcarrier is obtained by doubling the 19-kHz pilot signal. [✓ True] or False?



AM BROADCAST SUPERHETERODYNE RECEIVER

SEP 17 1976

UNIT EXAMINATION 75
ANSWER SHEET

GRADE 88

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UE75A

SEP 17 1976

Write your answers in the space provided. Be sure to include units, such as volts, μF, etc. where necessary. **RETURN ONLY THE ANSWER SHEET FOR GRADING.** Keep the exam for your records.

1. No
2. False
3. False
4. 250 KHz
5. Beta
6. signal generator
7. audio amplier & tuned radio freq. radio recvr.
8. X .1 volt
9. X yes
10. substitute a good one
11. decrease
12. none
13. volume control
14. low
15. 455 KHz
16. X Increase
17. grounded
18. X True
19. 10.7 MHZ
20. X check power & speaker

(Continued on reverse side)

21. all master

22. speaker

23. AC line

24. True

25. microphone & speaker

26. True

27. IHF sensitivity

28. False

29. yes

30. 4 Ω

31. False

32. out put

33. compare voltage measurements to same stage in other channel

34. poor low-frequency response

35. power

36. wow

37. drive - pulley

38. False

39. strobe

40. lateral & vertical

41. less

42. none

43. .25 mil

44. False

45. True

46. cross modulation

47. L C circuits

48. 19 KHz

49. False

50. True

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